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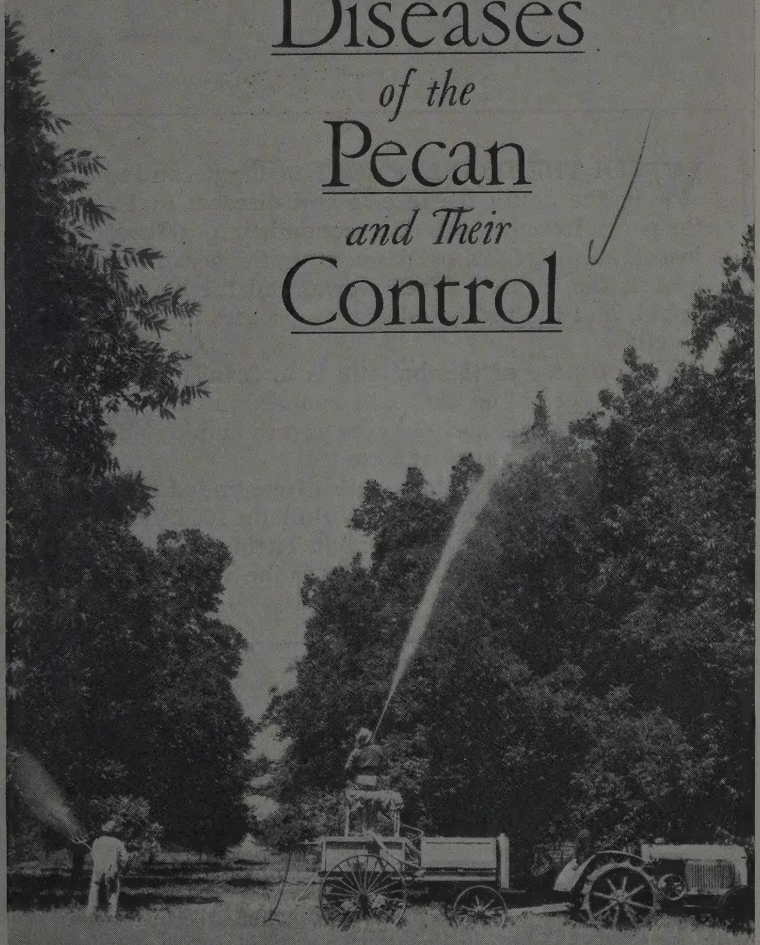
Insects and Diseases of the Pecan and Their Control



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1940

WITH THE DEVELOPMENT of the pecan industry in the South the insects and diseases that attack the pecan have increased in economic importance. The insects causing the most damage are the pecan nut casebearer, the hickory shuck worm, and the black pecan aphid, and the most destructive diseases are scab and rosette.

The purpose of this bulletin is to furnish the pecan grower information that will enable him to recognize these insect pests and diseases and to employ effective control measures against them.

This bulletin gives the results of continued investigations and supersedes Farmers' Bulletin 1654, Insects of the Pecan and How to Combat Them, and Farmers' Bulletin 1672, Diseases of Pecans in the Southern States.

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INSECTS AND DISEASES OF THE PECAN AND THEIR CONTROL

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INSECTS OF THE PECAN

INTRODUCTION

THE DEVELOPMENT of pecan growing into a specialized industry has resulted in an intensification of the problems of insect control. As plantings have been made in new areas, many of the insects feeding on the pecan in its native habitat have followed it, and in addition many other insects have transferred their attention to the pecan from native hickories or other trees nearby. The problem of insect control on pecans has also been complicated by the increased tendency toward the growing of this crop in more or less extensive areas under orchard conditions. Finding themselves in the midst of an abundant supply of their preferred food, the insects become exceedingly numerous, and consequently difficult to control.

INSECTS INJURING THE NUTS

PECAN NUT CASEBEARER

One of the most important insects attacking the pecan is the pecan nut casebearer (*Acrobasis caryae* (Grote)).[1] In Texas it has often been reported as destroying from one-third to three-fourths of the total pecan crop. It is also present in Louisiana, northern Florida, and in Georgia, Alabama, and Mississippi, damaging from 5 to 40 percent of the crop each year.

Seasonal History, Habits, and Injury

The nut casebearer passes the winter as a partly grown larva in small, tightly woven cases, similar to those of the leaf casebearer

Figure 1.—Pecan shoots showing spring injury by larvae of the pecan nut casebearer.

(fig. 24), usually situated at the place where a bud joins the stem. The larvae become active during the latter part of March or early in April, the exact time depending upon the season and the latitude. At first they feed a short time on the buds to which the cocoons are attached; later they bore into the young tender shoots (fig. 1) where a leaf joins the main stem. After feeding for 2 weeks or more, the

[1] Formerly erroneously called *Acrobasis hebescella* Hulst.

larvae transform to the pupal, or resting, stage within the tunneled shoots.

When mature, the larva (fig. 2) is about half an inch long, and its general color is a dirty olive green. The pupa (fig. 2) is about one-third of an inch long and when first formed has a decided olive-green cast, but later it is brown and without striking markings. After a pupal period of 11 to 18 days, moths appear. In southern Georgia this is usually between May 7 and 24. The appearance of the maximum number of moths coincides fairly well with the setting of the nuts.

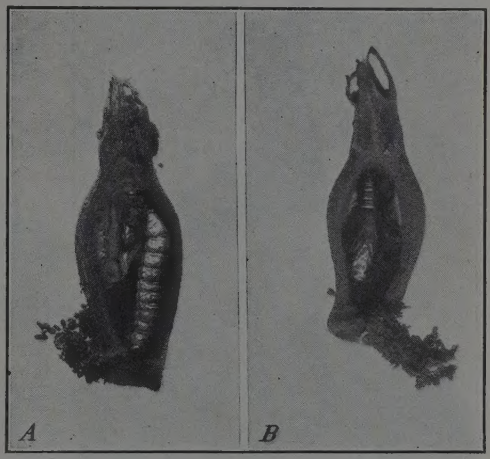

FIGURE 2.—Larva (*A*) and pupa (*B*) of the pecan nut casebearer within small nuts.

The moth (fig. 3) is of a rather inconspicuous dark-gray color, with a ridge or tuft of long, dark scales extending across each forewing near the middle. It measures about five-eighths of an inch across the expanded wings. The moths usually begin to lay their tiny, inconspicuous, greenish-white eggs from 2 to 4 days after emergence, placing them singly on the outer end of the nut, and usually at or near the base of the calyx lobes (fig. 4). Apparently it is the habit of moths to lay but one or two eggs on a cluster of nuts.

FIGURE 3.—Moth of the pecan nut casebearer. 3 times natural size.

The most important damage is caused by the first-generation larvae, which appear in May and early in June and bore into the recently set nuts. At the point of attack, near the stem end, they cast out characteristic masses of borings (fig. 5), which are held together by fine silken threads, eventually forming a short silk-lined tube. The flimsy web thus formed

probably protects the larvae from the attacks of predatory and parasitic insects while they are entering the small nuts and also holds the nuts together in the cluster, preventing them from dropping to the ground before the larva is mature.

FIGURE 4.—Egg of the pecan nut casebearer. 12 times natural size.

In the course of its feeding and development, which takes about 26 days (fig. 2), a single larva of this generation may hollow out and destroy from two to five of the small nuts in the cluster. The larvae of the second generation attack the nuts in the same manner, but the loss is usually less, since the nuts are larger and only one or two are required for the development of the larva (fig. 6).

The larvae of the later generations usually cause very little damage. They seem to prefer the shucks, and in these they gnaw only through the surface, which apparently does not interfere with the development of the nuts.

Usually there are but three generations of this insect in a year, although in Texas four generations have occurred in some years. The

FIGURE 5.—Buds and young nuts showing injury by larvae of the pecan nut casebearer.

larvae of the last generation in the season do not mature in the fall, but after feeding for a time they leave the nuts to construct their hibernation cases about the buds.

The approximate times of appearance of the different stages and activities of the pecan nut casebearer in northern Florida or southern Georgia are shown in figure 7. The periods will vary, however, according to the locality and the season.

Control

Spraying when the nuts are small, shortly after the first-generation eggs begin to hatch, is the most effective method of dealing with this

FIGURE 6.—Cluster of nuts infested by the pecan nut casebearer.

insect. In southern Georgia, northern Florida, and Texas a high degree of control has been obtained with two applications of a spray of 13 fluid ounces of nicotine sulfate combined with 3 quarts of mineral-oil emulsion (white- or summer-oil type), or with 1 quart of fish oil, in each 100 gallons of water. In many cases a single application has given as good results as two.

Under the semiarid conditions in Texas, good control of the nut casebearer has resulted from spraying the trees with lead arsenate at a strength of 6 pounds in 100 gallons of water, confirming the results obtained by the Texas Agricultural Experiment Station. Two applications of spray were made in many of the experiments, but a single properly timed spray application has been found effective.

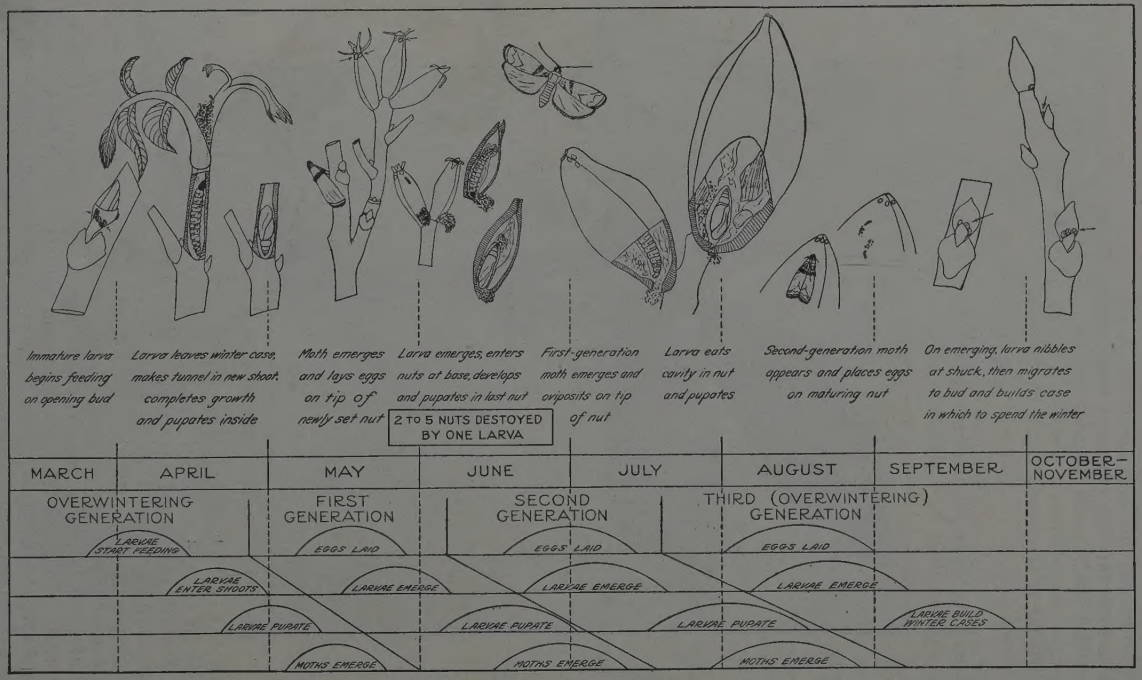
Immature larva begins feeding on opening bud
Larva leaves winter case, makes tunnel in new shoot, completes growth and pupates inside
Moth emerges and lays eggs on tip of newly set nut
Larva emerges, enters nuts at base, develops and pupates in last nut
2 TO 5 NUTS DESTOYED BY ONE LARVA
First-generation moth emerges and oviposits on tip of nut
Larva eats cavity in nut and pupates
Second-generation moth appears and places eggs on maturing nut
On emerging, larva nibbles at shuck, then migrates to bud and builds case in which to spend the winter
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER–NOVEMBER
OVERWINTERING GENERATION
FIRST GENERATION
SECOND GENERATION
THIRD (OVERWINTERING) GENERATION
LARVAE START FEEDING
EGGS LAID
EGGS LAID
EGGS LAID
LARVAE ENTER SHOOTS
LARVAE EMERGE
LARVAE EMERGE
LARVAE EMERGE
LARVAE PUPATE
LARVAE PUPATE
LARVAE PUPATE
LARVAE BUILD WINTER CASES
MOTHS EMERGE
MOTHS EMERGE
MOTHS EMERGE

FIGURE 7.—Seasonal history of pecan nut casebearer in southern Georgia.

Lead arsenate is injurious to pecan foliage under humid conditions, and this treatment is probably unsafe except in semiarid or arid climates.

For effective control the spray applications must be accurately timed and must be made before many of the first-generation larvae have entered the nuts. This period is short and varies with the season and the locality, but in general the spraying should be done soon after the nuts have formed and most of the tips, or stigmas, have turned brown, which is usually late in May or early in June. If two applications are made, they should be about a week apart.

If it is necessary to use bordeaux mixture for the control of scab at the time when a spray for the nut casebearer should be applied, nicotine sulfate may be used in combination with the fungicide.

PECAN WEEVIL

The pecan weevil (*Curculio caryae* (Horn)), often known as the hickory-nut weevil, is in some sections a serious obstacle to the production of pecans. It is found wherever there are pecans or

FIGURE 8.—Grubs, or larvae, of the pecan weevil within the nuts.

hickory nuts in the eastern half of the United States, but the greatest damage to pecans occurs in the Piedmont of North Carolina, South Carolina, Georgia, and Alabama, and in certain parts of Mississippi, Louisiana, and Texas. This insect often seems to be slow in becoming established in a locality but is very tenacious when once it does, and may cause increasing losses in an orchard through a period of years.

Pecan varieties differ widely in their susceptibility to attack by the weevil. The nuts of the Stuart, Schley, and Rome varieties, which are the first to fill, suffer the heaviest losses; other standard varieties, which form kernels later, have been largely free from attack.

NATURE OF INJURY

The first damage of the season occurs in midsummer, when adult weevils puncture the nuts while they are in the "water stage," that is, before the kernel has formed. Injured nuts are often stained by juice coming from the puncture. They develop dark patches on the surface, in a few days fall from the tree, and will be found to be

discolored and empty. The result of such an injury is similar to black pit, a condition caused by the feeding of certain sucking insects (p. 12). The better known and more important injury caused by the pecan weevil is the destruction of nuts in the fall by the grubs or worms. The kernel may be entirely destroyed by the larvae, leaving only a black powdered refuse (fig. 8).

In emerging from the nuts, the grubs make holes about one-eighth of an inch in diameter (fig. 9, *A*, *b*). Infested nuts on the tree (fig. 9, *A*, *b*; *B*, *b*) are made conspicuous by the fact that the shucks fail to separate from the shell at the time normal nuts are opening.

Seasonal History and Habits

The adult weevil (fig. 10) is light brown or grayish in color, unless the scales are rubbed off, when it becomes dark reddish brown.

Figure 9.—Good pecan nuts, with shucks opening (*a*); nuts infested with the pecan weevil, with shucks remaining closed (*b*). Hole in second nut from left (*A*, *b*) where weevil grub left the nut.

The beak of the female is half an inch long, or slightly longer than the body; the male's beak is about half as long as that of the female. On the tip of the beak are two minute teeth that make it an excellent drill. The adult weevils are active in the trees from about July 15 to September 20.

As soon as kernels develop, which in the earliest varieties of pecans is about September 1, the female weevils drill holes through well-hardened shells of either hickory or pecan nuts and place two to four or more eggs (fig. 11) in separate pockets through one puncture. The eggs hatch in a week, and the grubs become full grown in about a month. The mature larvae begin emerging from nuts the last of September or the first of October, and about 70 percent enter the soil during this month, although they continue to do so until December or January. The larvae then form cells 1 to 10 inches below the

surface by pressing back the surrounding earth. A heavy compact soil is apparently more suitable than a sandy soil, and the larvae go deeper in cultivated than in uncultivated soils. Pupation takes place in the bare cell the first or second fall after the grubs leave the nuts, and the adult weevil forces its way up through the ground the following summer. The weevils appear in large broods every other year, smaller broods appearing in the alternate years. In most localities the heaviest infestations have occurred during the even years—1932, 1934, etc.

FIGURE 10.—Adults of the pecan weevil, male at left, female at right. 2½ times natural size.

CONTROL

Jarring the trees during the period of adult activity is the most satisfactory control for this insect. During August, before egg laying begins, most of the weevils are on the lower limbs, and the grower need jar only those parts of the trees. Later the adult weevils are present throughout the trees, and jarring should then be more general.

A sheet and a padded pole are required for jarring. The sheet should be about 15 to 30 feet long, depending on the spread of the branches, and half as wide. Regular picking or harvesting sheets may be used for the purpose. The pole may be padded with a piece of automobile tire or similar material. A strip of wood should be fastened at each end of the sheet to hold it open so that it can be carried by two men, who walk around the trees keeping the sheet under the outer branches. A third man walks around near the trunk, striking the branches with the pole as the sheet is brought under them. One or two sharp raps on each limb are sufficient. It will be necessary to climb high trees and jar each of the upper branches. The weevils that fall on the sheet can be mashed or put into a can of kerosene.

FIGURE 11.—Eggs of the pecan weevil in a pecan kernel. 3 times natural size.

Jarring can be done at any time of day, as the weevils do not fly readily. For thorough control about six jarrings should be made during the season, starting the last of July or early in August. The time intervals depend somewhat on rainfall, as the emergence of weevils is dependent on the softening effect of rain on the soil. The frequency of jarring must be judged by results, for the greater the number of weevils caught the greater is the need of further jarring.

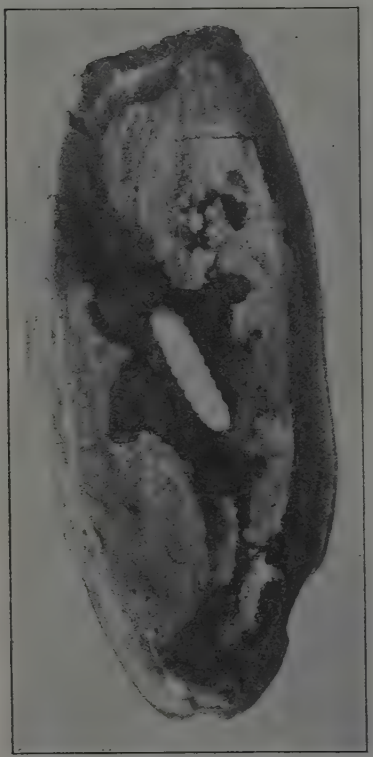

FIGURE 12.—Larva of the hickory shuck worm in shuck of a nearly mature pecan nut. Twice natural size.

The nuts in weevil-infested orchards should be harvested as early as possible, even though some of the weevils will have already left the nuts. Nuts that may be infested should be placed in tight-bottomed containers or, better, on a tight floor, so that the emerging grubs cannot reach soil and complete their development. Later the good nuts can be picked out.

It is best not to try to grow varieties of pecans susceptible to the pecan weevil in the vicinity of hickory trees. Pecan weevils, as well as several other pecan pests, breed in hickory nuts. A grower will find different parts of his orchard affected to different degrees, and the same trees severely infested each year. Knowing the parts of his orchard that suffer most, a grower can concentrate his efforts in those trees. As orchards become older, however, weevils become more evenly distributed, and local differences in degree of infestation tend to disappear.

HICKORY SHUCK WORM

During the fall a small white larva or worm (fig. 12), about three-eighths of an inch in length, may be found mining the shucks of pecan and hickory nuts. This larva is commonly called the hickory shuck worm (*Laspeyresia caryana* (Fitch)). It is one of the most important pecan insects and frequently causes serious damage to the nut crop in practically every section of the pecan belt. During the summer and early fall before the shells begin to harden, the larvae destroy the nuts by mining and eating out the interior, often causing a condition similar to black pit (p. 12) and resulting in considerable shedding of immature nuts in some seasons. After the shells have

hardened, the larvae mine or tunnel the shucks, preventing the proper development of the nut kernels and interfering with the natural separation of the shucks from the shells. Nuts infested by shuck worms are likely to be undersized and to mature later than those free from this pest, and the shell is often stained.

This insect also feeds upon various species of hickory, and the injury is similar to that done to the pecan. Occasionally the larvae are found subsisting on the galls formed by certain species of phylloxera (p. 21).

Seasonal History and Habits

In the northern parts of the pecan-growing region the shuck worm has one or two generations a year; farther south it may have as many as five generations, according to the season. In northern Florida and southern Georgia the first moths, which develop from larvae that have spent the winter in fallen pecan or hickory shucks, begin to

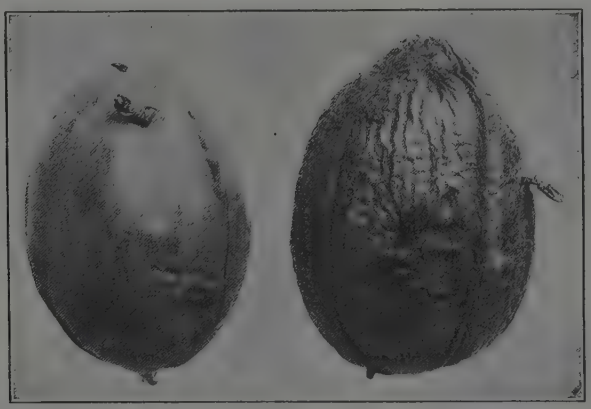

Figure 13.—Pupal skins of the hickory shuck worm protruding from shucks of pecan nuts.

appear the middle of February, and the maximum emergence usually occurs during April. The development of the insect seems to be timed for the development of the nuts of the pignut (*Hicoria glabra* (Mill.)), the mockernut (*H. alba* (L.)), and similar species which develop 2 or 3 weeks earlier in the spring than the pecan. Most of the spring brood of moths die before the pecan nuts have set, and it is difficult to find a pecan nut infested with the hickory shuck worm before the middle of June.

The moths, which are inconspicuous and rarely noticed in the orchard, deposit their small, whitish, flattened eggs on the shuck of the nut. Upon hatching, the tiny larvae gnaw their way into the green nuts. Until the shells harden, they work more in the interior of the nuts than in the shucks and cause many of the immature nuts to shed. Before transforming to the pupal stage, the larva prepares a small silk-lined cocoon and cuts a circular hole in the shuck to permit the moth to escape. Just before emergence of the moth the pupal skin is extended a short distance through the circular cut (fig. 13),

the lid of which remains attached to the nut in a sort of trap-door arrangement.

With each succeeding generation there is a very rapid increase in population of this insect. The worms of the last generation, which attack the nearly mature nuts with hard shells, feed only on the shucks, in which they mine and attain full growth before cold weather. They pass the winter as larvae in the shucks on the ground or in shucks that remain on the trees.

Control

No satisfactory control for the shuck worm can be recommended at the present time. Considerable experimental work with various

Figure 14.—*A*, Southern green stinkbugs; *B*, leaf-footed bugs. 1½ times natural size.

insecticides has been carried out and is still being continued. Attention is also being given to sanitation methods, such as the disposal, during the winter months, of pecan shucks containing the larvae and plowing under the shucks early in the spring.

SOUTHERN GREEN STINKBUG AND OTHER PLANT BUGS

Black Pit and Kernel Spot

Black pit and kernel spot of the pecan are caused by the feeding of sucking insects upon the immature nut. These types of injury are well known over the pecan belt and frequently become serious to an individual grower. They are found to recur irregularly in restricted sections, being abundant one year and practically absent

the following year. Both these troubles are caused by the feeding of the southern green stinkbug (*Nezara viridula* (L.)), the leaf-footed bug (*Leptoglossus phyllopus* (L.)), and closely related species (figs. 14 and 15). Certain similar conditions are caused by the pecan weevil and the hickory shuck worm, discussed earlier in this bulletin.

Black pit is a blackening of the interior of the green pecan. The affected nuts always drop prematurely. The midsummer drop often attributed to other causes is in some cases probably due to black pit caused by the feeding of these sucking insects. The affected nuts sometimes show brown or black spots or stains on the shuck, which often spread over the entire surface soon after the nuts drop.

These sucking insects begin feeding about the time the nuts reach the water stage, or approximately July 1, and continue until the nuts are practically mature. However, the punctures made after the nuts have passed the water stage do not produce black pit, but instead a condition known as kernel spot, which consists of dark brown or black spots on the kernels (fig. 16). An affected kernel may have several spots varying in diameter from one-sixteenth to three-sixteenths of an inch. Although the surface of the spot is dark, the internal part is whitish. The spots are pithy and porous and are decidedly bitter, but this bitter taste is not imparted to the unaffected portion of the kernel. This injury cannot be detected until the shells have been removed.

FIGURE 15.—Southern green stinkbug on pecan nuts.

SEASONAL HISTORY AND HABITS OF THE SOUTHERN GREEN STINKBUG

As the various plant bugs that cause black pit and kernel spot have similar habits, this account will deal chiefly with the southern green stinkbug. This bug is usually light green, although adults collected during the colder months are much darker, with a purplish or pinkish tinge. The adult is shield-shaped (fig. 15), which is the characteristic form of the members of the stinkbug family, and is about half an inch long.

This insect passes the winter in the adult stage and often leaves its winter quarters during periods of mild weather. The eggs are laid

in clusters of 36 to 116 on the under side of the foliage, from early in April until the middle of November. The immature bugs vary greatly in color pattern but have the general shape of the parent insects. It is probable that this species may develop four full generations annually in the extreme southern portion of the pecan belt.

The southern green stinkbug is found through the southern tier of States from South Carolina to California. It attacks a wide

FIGURE 16.—Kernel spots on Schley pecans. The upper and central views show the location of the spots on the ridges and edges of the kernels. The three lower views of kernels, cut through the spots, show the depth and extent of the injury.

variety of plants, including truck crops, cover crops, fruit trees, and numerous weeds. Certain members of the mustard family, such as radish, collards, and turnip, and several legumes, including cowpea, beggarweed, and *Crotalaria* or rattlebox, are preferred. These plants serve as breeding hosts, that is, the plants on which eggs are laid and the young develop. Pecan nuts are attacked only by the adult bugs which fly from the breeding hosts. The leaf-footed bug breeds on thistle, yucca, basketflower, jimsonweed, and cowpea.

Control

For the control of the southern green stinkbug and other species of bugs that cause black pit and kernel spot, the grower must depend chiefly on the use of proper cover crops and intercrops, and on orchard sanitation. Insecticides, hand picking, and trap crops have been found impractical in pecan orchards.

In the past cowpeas have been commonly used to provide humus, but the cowpea is a favored host of the stinkbug and other plant bugs, and the worst outbreaks of kernel spot have been reported from pecan orchards planted to cowpeas or adjacent to large fields of cowpeas that have been cut for hay. The soybean and certain species of *Crotalaria* are unsafe to use for the same reason, and none of these crops should be planted in a bearing orchard. Fortunately, the velvetbean is practically free from the attacks of this insect and therefore can be safely used among pecans.

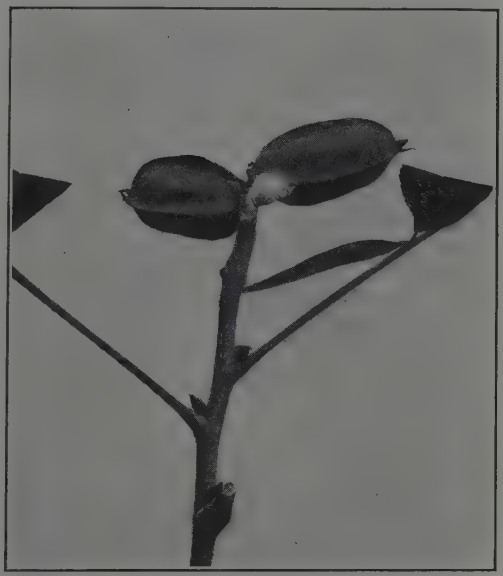

FIGURE 17.—Pecan nut cluster showing spittlelike substance produced by the spittle bug.

Pecan growers who do not plant summer cover crops of any kind should practice a system of cultivation to keep down weeds and native vegetation, which are likely to include host plants, during the summer and early fall. This does not necessarily mean clean cultivation; disking the orchard two or three times should be sufficient.

Many of the hibernating adults can be killed by thorough sanitation in winter. This applies to certain other pests also and is good orchard practice. Fence rows in particular should be cleared.

SPITTLE BUG

The presence of a spittlelike, frothy substance on small pecan nuts and about the buds or tender growing shoots (fig. 17) during the spring and early summer sometimes causes concern to pecan growers. This substance is produced by the young of one of the so-called froghoppers or spittle bugs, *Clastoptera obtusa* (Say), which suck the sap from the tender buds on newly formed shoots early in May, and later from the nut clusters. The frothy masses presumably protect the young, or nymphs, and it is easy to see that they are fairly well guarded against many of the smaller kinds of insect enemies.

CONTROL

This species does not cause serious injury, and ordinarily it is not necessary to spray against it. It has been found, however, that while this insect is present under the spittlelike substance early in the summer it is very readily killed with nicotine. If the trees are sprayed for the control of pecan scab the middle of May, nicotine sulfate at

FIGURE 18.—Injury to young buds in spring caused by larvae of the pecan leaf casebearer.

the rate of 1 to 1,000, or 13 fluid ounces combined with each 100 gallons of bordeaux mixture, will control the insect. Where bordeaux is not being used, nicotine sulfate will give equally good results when combined at the rate of 13 ounces with summer-oil emulsion 3 quarts to 100 gallons of water.

INSECTS INJURING THE FOLIAGE AND SHOOTS

PECAN LEAF CASEBEARER

The pecan leaf casebearer (*Acrobasis juglandis* (LeB.))[2] has been reported from many localities on both pecan and hickory, but it ranks

[2] Formerly called *Acrobasis palliolella* Rag., and also erroneously known as *Acrobasis nebulella* Riley.

as a serious pest of pecan only in northern Florida and the southern parts of Georgia, Alabama, Mississippi, Louisiana, and Texas. The most serious damage by this pest is done early in the spring by the worms, which emerge from their winter cases and feed voraciously upon the unfolding buds and leaves (figs. 18 and 19). Badly infested pecan trees are frequently kept in a defoliated condition for weeks during the spring by the attacks of this insect. When abundant, the larvae may also attack the pistillate blossoms, greatly reducing the yield.

FIGURE 19.—Injury to foliage and flowers by larvae of the pecan leaf casebearer.

SEASONAL HISTORY AND HABITS

Only one generation of the pecan leaf casebearer develops during the course of a year. The small caterpillar is brown, but it soon changes to dark green. The full-grown larva measures a little over one-half inch in length (fig. 20). Some of the larvae reach full growth by the last of April, but the majority do not mature until May or early in June.

The larvae transform to pupae within their cases (figs. 20 and 21), spinning a flimsy layer of silk over the free ends of their cases just before pupating. The pupa (fig. 22) is a deep, shiny mahogany brown. The pupal period averages about 17 days.

The moths make their appearance from about the middle of May until the first week in August, the greatest number being present during the latter half of June. They measure about two-thirds of an inch across the expanded wings, which are a mixture of gray and brown. The body is white or dusky gray.

The eggs of the leaf casebearer are deposited always on the under side of the leaves, usually near the junction of the vein with the midrib. They hatch from a little after the middle of May until early in August, according to the weather. Throughout the summer and early fall the larvae feed very sparingly on the under side of the leaves, slowly building little winding cases (fig. 23), which afford good protection for them. Although they may feed for nearly 3 months, or even longer, they rarely attain a length greater than one-sixteenth of an inch by fall. During the latter part of September, or shortly before the leaves begin to drop, the little larvae leave their summer quarters and establish themselves around the buds, where

they construct small, compactly woven, oval cases known as hibernacula (fig. 24).

Control

Investigations carried on in Georgia have shown that the leaf casebearer can be controlled by spraying with calcium arsenate. Only one thorough application, early in July, is necessary. To prevent injury to the foliage or nuts, calcium arsenate should always be used with bordeaux mixture. Two pounds of calcium arsenate to 100 gallons of bordeaux is recommended. If a fungicide is needed for scab control at that time, the bordeaux mixture should be of the usual strength, 6–2–100, but on varieties that do not scab the strength may be reduced to 2–1–100, which is sufficient to prevent arsenical injury to pecan foliage. The spray should be thoroughly applied to the under side of the leaves, where the larvae feed.

Figure 20.—Larva and case of the pecan leaf casebearer. Twice natural size.

Black Pecan Aphid

One of the most destructive defoliators of pecan trees in many localities is the black pecan aphid (*Melanocallis caryaefoliæ* (Davis)). It seems to prefer such varieties as the Schley, Alley, Van Deman, and Stuart, whereas Curtis, Moore, and Moneymaker usually escape injury. This aphid generally increases most rapidly during the season on pecan trees that have received a number of applications of bordeaux mixture, the infestation becoming especially noticeable during the latter part of the summer. However, in some seasons and localities trees not sprayed with bordeaux mixture may become heavily infested.

Nature of Injury

Bright yellow leaf spots, roughly rectangular in shape, are the first signs of the presence of the black aphid, which sucks its food through a small puncture in the surface of a leaflet, apparently injecting a poison that destroys the chlorophyll. The spotted section of the leaflet is killed and eventually turns brown, and the presence of many feeding spots causes the whole leaflet to drop prematurely (fig. 25). The central portions of the trees are likely to show the first injury. Spotting of the foliage may be found as early as May, but usually it is August or September before extensive defoliation occurs (fig. 26).

This premature defoliation has a direct effect on the current pecan crop by cutting off the supply of plant food and thus preventing the proper filling of the nuts, and it also has an adverse effect on production the following year.

Seasonal History and Habits

This insect passes the winter in the form of tiny black eggs, which were laid in crevices in the bark by the last fall generation. In the spring the eggs hatch and the aphids move to the opening buds and leaflets, where they feed until they become adults, all of which are winged females. The young aphids, about one-hundredth of an inch in length, are pale green, but as they feed they soon turn a darker green.

The full-grown aphid is about one-sixteenth of an inch long, exclusive of wings and antennae. The body is a very dark green with a series of large black humps on the back and sides. This aphid can jump with surprising agility.

Figure 21.—Larvae of the pecan leaf casebearer in their cases and injury done to pecan leaflets.

During the growing season and until fall the adults produce living young, which move some distance from the mother before they settle down to feed. As a result this species is not found in crowded colonies, as are many other plant lice. This aphid feeds on both sides of the leaves, though adults are usually found on the lower surface. They prefer hardened leaves and also seem to prefer the shaded inner branches of the trees.

Figure 22.—Pupa of the pecan leaf casebearer. 2½ times natural size.

About 15 generations of females follow one another through the season, each adult producing 75 to 100 young. The aphids may thus attain enormous numbers by the last of the summer, though they may have been scarce early in the spring.

Control

The black pecan aphid can be controlled by thorough spraying with nicotine sulfate (40 percent nicotine) at a strength of 1 to 4,000 (3.2 ounces per 100 gallons) combined with either bordeaux mixture, as used for the control of pecan scab, or with a summer-oil emulsion containing 0.5 percent of oil (2 quarts

per 100 gallons). Aphids are usually not present in sufficient numbers to warrant spraying until some time in June, or until at least 3 weeks after the second cover spray for pecan scab, which is applied in May. The number of applications must be determined by each grower after careful observation in his own orchard. Special attention should be given to orchards regularly sprayed with bordeaux mixture, since such orchards are particularly susceptible to infestation by the black aphid. The results are likely to be unsatisfactory unless the spray is thoroughly applied to all parts of the trees.

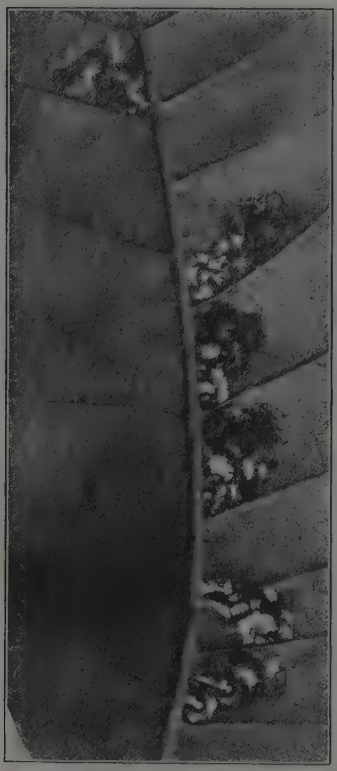

FIGURE 23.—Injury to lower surface of pecan leaf by newly hatched larvae of the pecan leaf casebearer. 2½ times natural size.

FALL WEBWORM

The insect noticed perhaps most commonly in a pecan orchard, especially late in the summer and in the fall, is the fall webworm (*Hyphantria cunea* (Drury)), which constructs unsightly nests or webs over the twigs and foliage (fig. 27). Trees defoliated late in the summer produce poorly filled nuts and bear little or no crop the following year. The spring brood of moths (fig. 28), which usually are pure white but sometimes have black or brown spots on the forewings, emerge in April and May. The greenish-white eggs are deposited in masses (fig. 28) on the leaves and hatch in about a week. Each colony forms a web in which all the caterpillars feed, eating the upper and lower surfaces of the leaves. When they need additional leaves for food, they enlarge the web, which may become a foot or more across.

The full-grown worms (fig. 27) usually measure a little more than an inch in length and are covered with long white and black hairs. On reaching maturity they leave their webs and transform to brown pupae in flimsy, hairy cocoons beneath rubbish on the ground, under the scales of bark, or just below the surface of loose soil. The moths of the first generation may appear by June 26, but most of them appear later in the summer. The second-generation larvae feed during the summer and fall. The insect passes the winter in the pupal stage in the cocoon.

CONTROL

The fall webworms may be controlled by spraying with calcium arsenate or lead arsenate at the rate of 1 pound to each 50 gallons of spray when the caterpillars are small. Bordeaux mixture should

be added to prevent injury to the foliage by the arsenical. When this insect is not abundant, it is more practical to remove the webs from the trees with a long-handled tree pruner or a long bamboo pole having a hook at one end.

WALNUT CATERPILLAR

In the South branches of pecan trees are often defoliated by colonies of the walnut caterpillar (*Datana integerrima* (G. and R.)), which when full grown is black with long whitish hairs and nearly 2 inches long. Small pecan trees, especially nursery stock, are sometimes completely defoliated, and it is not uncommon to see large branches on bearing trees stripped of their foliage.

Two generations of this insect occur in the South. The moths that develop from overwintering pupae emerge from April 15 to July 15, and shortly lay eggs (fig. 29) in masses of from one to several hundred on the under side of the leaflets. The eggs hatch in a little less than a week. The young caterpillars are brownish, with stripes. At first they feed only on the under side of the leaflets but later devour the entire leaf except the midribs and petioles.

FIGURE 24.—Winter cases of the pecan leaf casebearer around a pecan bud; 7 times natural size.

The caterpillars feed in colonies (fig. 30). When molting, the larger ones invariably leave their feeding places and crawl to the trunk or larger limbs, where they shed their skins in a mass, which may adhere to the bark for several weeks or longer. After molting they ascend the tree to continue their feeding depredations. When full grown, after a feeding period of 25 days or more, the worms crawl down the trunk and immediately enter the soil to a depth of a few inches. Here in a day or two they transform to brown pupae. In some localities a second generation of caterpillars feeds late in the summer and in the fall.

CONTROL

Where the walnut caterpillar is a serious annual pest, the same spray treatment should be used as for the control of the fall webworm. When found massed on the tree trunks in the act of molting, the larger larvae may be destroyed by crushing or by some other suitable means.

PECAN PHYLLOXERA

Tumorlike swellings or galls (figs. 31) occasionally appear in large numbers on the leaves, leafstalks, nuts, and succulent shoots of both

native and improved varieties of the pecan. These galls are formed by tiny insects known as phylloxera, which are closely related to aphids. Reports of phylloxera injury have come from practically all sections where the pecan is grown, but severe damage is most prevalent in Louisiana, Mississippi, and Arkansas.

FIGURE 25.—Pecan leaflet injured by the black pecan aphid.

One of the most destructive species found on pecan is the pecan phylloxera (*Phylloxera devastatrix* Perg.). It may attack any part of the current season's growth, including leaves, leaf and leaflet stems, twigs, and nuts. The attack of this insect causes the twigs to become malformed, devitalized, and finally to die; foliage is lost, nuts attacked are deformed and drop, and nuts growing on attacked twigs drop prematurely or fail to fill properly. In extreme cases entire limbs may die. Pecan varieties vary greatly in their susceptibility to attack by phylloxera; Schley, Stuart, and Success are especially liable to injury.

The young insects, barely visible to the eye, first appear in the spring on the unfolding buds, where they insert their beaks and begin to feed. This stimulates the growth of a gall, which soon envelops the insects. The developing galls are green to yellow green, occasionally tinged with red; mature galls are brown or black. The gall-building insect develops to maturity within the gall and then deposits eggs in large numbers therein. These eggs hatch into young nymphs, which develop into mature winged forms within. Then the gall splits open into several sections and releases them, usually by the last of May or the first of June. The species hibernates in the egg stage in protected places on the branches.

CONTROL

Satisfactory control has been obtained with spray mixtures containing 13 fluid ounces (slightly more than three-quarters of a pint) of nicotine sulfate to 100 gallons of water with the addition of one of the following: 4 pounds of potash-fish oil soap, 2 quarts of lubricating-oil emulsion, or 2½ gallons of liquid lime-sulfur. The spray

FIGURE 26.—Pecan trees showing premature defoliation caused by the black pecan aphid.

FIGURE 27.—Web and caterpillars of the fall webworm.

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FIGURE 28.—Moth and egg mass of the fall webworm. Twice natural size.

should be applied late in the dormant period up to the time when the swelling buds show about half an inch of green. The combination of nicotine sulfate with lime-sulfur has given the best results and is recommended for use against severe infestations. For light to moderate infestations either of the other combinations should prove sufficiently effective. It is essential that all applications be thorough and that all parts of the trees be covered by the spray. None of these combinations has caused any injury to the trees in any test in which they have been used.

PECAN CIGAR CASEBEARER

The pecan cigar casebearer (*Coleophora caryaefoliella* (Clem.)) sometimes inflicts serious damage on the buds and foliage in pecan orchards during the spring months, although it is usually considered a pest of minor importance. This insect also feeds upon hickory and black walnut. It is distributed over a wide range, extending from Florida to the western border of Texas and as far north as New Hampshire, but the greatest damage to the pecan is along the Gulf coast.

The insect hibernates as a partly grown larva in its case, attached to the trunk of the tree or a large limb. As the buds of the pecan open, the hibernating larvae become active and attack them, continuing to feed on the foliage (fig. 32) until about the middle of May (in Florida), when they become full grown. There are several generations during the growing season.

FIGURE 29.—Egg mass of the walnut caterpillar. 2½ times natural size.

CONTROL

In pecan orchards in which arsenical spraying is regularly practiced, the cigar

casebearer is rarely a source of trouble. If this insect becomes abundant in the spring, calcium arsenate should be used at the rate of 2 pounds to each 100 gallons of spray, with bordeaux mixture to prevent injury to the foliage by the arsenical.

PECAN BUDMOTH

The pecan budmoth (*Gretchena bolliana* (Sling.)) is primarily a bud feeder, and in attacking the terminal buds in pecan nurseries or on young orchard trees it causes a stunted growth as well as excessive branching. In bearing orchards it is rarely troublesome.

This insect passes the winter in the adult stage, a gray moth with blackish-brown patches and streaks, with a wing expanse of a little more than half an inch. As soon as the buds open, the moths begin to lay eggs, at first on the branches near the buds, but later on the leaves. The larvae feed about 25 days. The pupae usually are formed in rolled-up leaves or infested buds, but occasionally they can be found under bark scales or at the crown of the tree. Several generations occur each season.

FIGURE 30.—Colony of walnut caterpillars on on pecan twig.

CONTROL

As a nursery practice it is strongly recommended that the trees be given thorough cultivation and fertilization, as vigorously growing trees in the nursery usually unfold their terminal buds so rapidly that the larvae do not have time to inflict serious damage.

Spraying with calcium arsenate during the spring and summer, with bordeaux mixture added to prevent injury to the foliage by the arsenical, will help materially in holding this pest in check. As there are several generations of this insect, and as the trees are growing continuously during the spring and summer months, four or five applications should be made at intervals of 3 or 4 weeks. Nurserymen sometimes make four or five applications of bordeaux mixture for the control of nursery blight, and where the budmoth becomes serious in nurseries calcium arsenate may be combined with the fungicide.

MAY BEETLES

May beetles or June bugs (*Phyllophaga* spp.) are often reported as seriously defoliating pecan trees in the spring while the leaves and shoots are growing vigorously. Small trees surrounded by uncultivated land sustain the worst injury. The beetles feed at night; in the daytime they lie hidden just beneath the surface of the ground. These insects are well known from their habit of flying to lights.

The beetles or adults (fig. 33) are from one-half to three-fourths of an inch long, robust, and usually rich brown in color. They lay their eggs in the ground, and the larvae, which are the well-known white grubs, feed in the soil upon the roots of plants, particularly grasses. Two years or more are required for larval development.

FIGURE 31.—Galls of phylloxera on pecan twig.

CONTROL

The control of May beetles on pecan trees is difficult because of their resistance to poisons and the large numbers in which they sometimes occur. In recent experimental work in northern Louisiana control was accomplished by heavy applications of lead arsenate (with a corrective to prevent injury to foliage) early in the period of flight. In the case of small trees the beetles may be handpicked or shaken onto sheets on the ground at night, and destroyed.

Since the larvae of the May beetles feed in the soil, especially in sod land, they are seldom injurious in well-cultivated orchards unless close to uncultivated land. Fields in the vicinity of orchards are a source of infestation, but if the soil is plowed as often as once a year the May beetles are unlikely to become very numerous.

PECAN CATOCALA

A caterpillar occasionally found destroying pecan foliage in the spring is the catocala (*Catocala viduata* (Guen.)). When abundant, it is capable of doing considerable damage by stripping the leaves until only the petioles and stems remain.

The insect passes the winter in the egg stage. The eggs are deposited by the moths on the under side of bark scales in the fall.

They hatch in the spring, and the caterpillars feed on the foliage throughout the spring and early summer. The caterpillars, which are gray, grow to a length of 2½ to 3 inches (fig. 34). When ready to transform, the larvae construct rather flimsy cocoons in which to pupate. The moths begin to appear the latter part of June and may continue to emerge until fall.

FIGURE 32.—Pecan leaves injured by larvae of the pecan cigar casebearer.

CONTROL

This insect rarely becomes sufficiently abundant to require special control measures. However, if it does become a serious pest, it may be controlled by applying arsenical sprays when the caterpillars are small. In some cases the arsenical may be combined with the bordeaux mixture applied for scab control in the second cover spray, in May.

GREEN LEAF WORM

Small spiny-looking worms, leaf green in color, appear on pecan trees in some sections of Louisiana at about the time the pistillate bloom appears and by their feeding give the leaves a shot-hole appearance. The holes are very small at first, but larger and larger ones are made as the worms develop. This worm, called the

FIGURE 33.—Adult May beetles. Natural size.

green leaf worm, is the larva of a sawfly technically known as *Isodyctium* sp.

The adults, which are small, beelike insects about one-fifth of an inch long, emerge from the ground in April and deposit small pale-green eggs in the tissue of new tender leaflets.

When newly hatched the larvae are about one-tenth of an inch long, and when full grown they are about five-eighths of an inch long. They generally feed on the under side of the leaves and when not feeding usually rest along the outer margin on the lower leaf surface. When they are through feeding, the worms enter the soil to a depth of 1 to 3 inches, where they construct earthen cocoons in which to spend the winter.

FIGURE 34.—Full-grown larvae of the pecan catocola. Natural size.

Spraying with arsenicals as for other leaf-chewing insects has been found effective against this species. The sprays should be applied when the pistillate bloom is first present.

INSECTS INJURING THE TRUNK AND BRANCHES

OBSCURE SCALI

Several species of scale insects have been found attacking pecans, but the obscure scale (*Chrysomphalus obscurus* (Comst.)) appears to be the only one that is of widespread importance (fig. 35). This species is an important pest of both native and improved varieties in Texas, Louisiana, Arkansas, and Mississippi, and may be found to a lesser extent in other parts of the pecan belt. It also attacks oak, hickory, and other trees. It appears to be a more important pest of bottom-land than of hill-land orchards.

The obscure scale attacks all parts of the tree except the leaflets and nuts. It tends strongly to begin development on the lower, inner portions of the tree. Often one or more of the main leaders and their branches, or one side of the tree, is almost completely encrusted while the remainder of the tree shows only a slight infestation. The greatest injury comes from the gradual killing of branches less than 3 inches in diameter. Larger branches are seldom killed, though they may be weakened to such an extent that they will not produce nuts normally, if at all. The slow, progressive killing of infested branches

reduces the number of fruiting limbs, besides weakening the whole tree and rendering it more subject to attack by borers, other insects, and diseases.

FIGURE 35.—Obscure scale on pecan twigs: *A*, Natural size; *B*, 2½ times natural size.

SEASONAL HISTORY AND HABITS

This insect belongs to a group called scale insects from the fact that their soft bodies are protected by scalelike coverings. The coloring of this particular scale closely resembles that of the bark on which it rests. The cover of the adult female averages about one-eighth inch in length and one-tenth inch in width and narrows slightly from

front to rear. The cover of the adult male is oval and about half the size of that of the female.

This insect has but a single generation each year, and its entire life, with the exception of the brief crawler stage and the short active life of the adult male, is passed under the protection of the scale covering. The purple eggs are pushed out, a few at a time, into the cavity left beneath the scale cover by the retraction of the last body segment of the female. They hatch in a few days, and the newly hatched, minute, salmon-colored young, or crawlers, settle beneath the cover of their parent or of some old scale, or on the exposed surface of a limb or twig. Crawlers emerge in considerable numbers from about the middle of May or a little later until early in August. As soon as the crawlers settle, they insert their beaks and begin to form their waxy scale coverings. From this time on the female is stationary, never changing her position.

Control

The application of a lubricating-oil emulsion during the dormant period of the trees has been found the most effective control measure against this scale insect in Louisiana. Tests have indicated, however, that dormant pecan trees are especially susceptible to injury by oil sprays. Even at strengths as low as 3 percent, oils have under some conditions injured pecan wood. Applications made very early or very late in the dormant period have caused more injury than those made in midwinter. Weak, slow-growing trees are much more subject to injury than are vigorous trees. If the trees to be sprayed are in a weakened condition, not more than a 2-percent lubricating-oil emulsion should be used regardless of the degree of scale infestation. A 3-percent emulsion should be used for control of scale on healthy pecan trees.

FLATHEADED APPLE TREE BORER

The flatheaded apple tree borer (*Chrysobothris femorata* (Oliv.)), a destructive pest of young deciduous trees of many kinds, attacks young pecan trees wherever they grow. The injury results from the tunneling of borer grubs in the bark and sapwood of the trunk and larger branches. The first part of the tunnel is in the surface bark; then as the grub grows it gradually penetrates to the cambium and makes a burrow half an inch or more wide in the surface of the wood. Trees 2 inches or less in diameter may be girdled and killed, making it necessary to replace or rebud them after a seedling shoot grows up. Larger trees are more or less weakened, and the presence of one borer in a tree often leads to further attack.

Active flatheaded borers disclose their burrows by pushing a brown powder out of cracks in the bark, and they may cause sap to flow out and make whitish stains on the surface. There may be a dark sunken streak over the burrow, and after some time, possibly not until the burrow is vacated, the bark sinks and cracks considerably. Borers usually begin work on the south or southwest side of a tree trunk, and most of the injury is found in that quarter.

Two factors make for the abundance and destructiveness of flatheaded borers in the pecan orchard, the weakening of trees from any cause and the proximity of other host trees. Unthrifty trees or young trees that have been headed high or have been injured in cul-

tivation, by cold, or by sun scald are more subject to injury than are vigorously growing trees, but vigorous trees do not always escape infestation. The first 2 or 3 years in the life of an orchard are the most critical as regards borer infestation, because of the inevitable setback due to transplanting. Trees are particularly susceptible to borers if there is a shortage of rain the first year after planting.

FIGURE 36.—Adult beetle of the flatheaded apple tree borer. 3½ times natural size.

SEASONAL HISTORY AND HABITS

The adult beetles may be found in pecan orchards from spring to late fall, but they are most numerous during May and again in August and September. The beetles (fig. 36) are about one-half inch long, flattened, metallic in appearance, and dark gray on the back so that when they rest on a tree their color blends with the bark. The under surface of the beetle is of a bright copper color. Beetles like to sun themselves on tree trunks but quickly fly away when disturbed. They lay their eggs throughout the summer on sun-exposed parts of the tree trunks in small cracks in the bark, or often in an old borer injury or a pruning cut. The tiny grubs hatch and burrow into the bark, widening and deepening their tunnels as they grow (fig. 37). It appears that the weaker the tree, that is, the less active the growth, the quicker the grub goes down to the cambium layer to tunnel and feed .

FIGURE 37.—Larval burrow of the flatheaded apple tree borer in the trunk of a young pecan tree. Note the pupa at the end of the burrow.

The creamy-white borers are readily recognized by the greatly enlarged and flattened head, which contains strong muscles to operate the wood-tearing mandibles or jaws. At maturity the borer is about an inch long. A year or more is required for the development from egg to adult.

Control

The most important measure for preventing injury is the maintenance of vigorous trees by planting the orchard in fertile soil and following approved horticultural practices as regards cultivation, fertilization, and conservation of soil moisture. Newly transplanted trees should be given the best possible care, in order that they may become well established as quickly as possible. Injury to trees in cultivation is partly responsible for wood-borer attacks and should be avoided. Sources of infestation in the vicinity of the orchard should be eliminated as far as practicable. No prunings of any kind should remain in or near the pecan orchard during the spring and summer.

Much of the egg laying can be prevented by wrapping the trunks with heavy paper or burlap, which should extend from the ground to the branches and should be tied at the top and mounded with earth at the bottom. The wrappers should be in place from March to November, as eggs may be laid at any time during this period. Low heading of the trees and permitting shoots to grow up from the base to shade the trunk as much as possible also reduce the amount of egg laying.

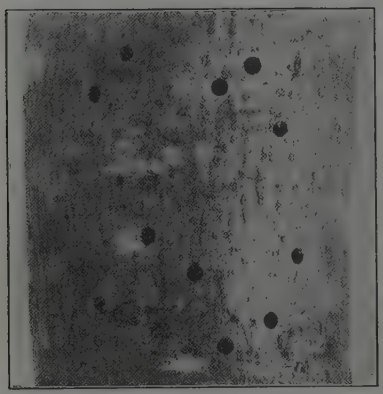

Figure 38.—Exit holes of adult beetles of the red-shouldered shot-hole borer.

When trees are infested, the borers should be removed with a knife. The wood should be cut as little as possible, as unnecessary cutting in live wood causes the bark to dry and invites further infestation by insects. The knife blade should be held flat against the tree and worked along the course of the burrow, the edges being trimmed later. The removal of bark and frass from the deeper part of the burrow is believed to hasten healing of the wound. The deeper parts should then be painted with a prepared pruning compound or with a mixture of 1 part of creosote and 3 parts of coal tar, to keep the wood from drying until the bark can heal over. Young trees should be examined at least once a year, preferably in March or April before mature borers emerge; and if the infestation is heavy, later examinations should follow during the summer for grubs overlooked the first time.

Red-shouldered shot-hole borer

The red-shouldered shot-hole borer (*Xylobiops basilare* (Say)) makes small, round holes in the bark of pecan and other trees (fig. 38). It attacks only trees or parts of trees that have been severely injured or are dying. Injury caused by severe drought or cold predisposes trees to attack by this insect. Several other similar species work on devitalized trees; some of them feed only on the bark and in the cambium region, while others go deep into the heartwood.

Control of these borers lies in keeping the trees in a healthy condition and reducing as far as possible sources of infestation near the orchard.

TWIG GIRDLER

Most pecan growers are familiar with the twig girdler (*Oncideres cingulatus* (Say)), which cuts off, or prunes, pecan twigs during the late summer and early fall. This beetle has a wide range and attacks many kinds of deciduous trees, although in the South it seems to confine its attacks for the most part to pecan, hickory, and persimmon.

When the beetles are abundant, they may do much damage by severing branches. It is not uncommon to see the ground under pecan or hickory trees literally covered with twigs, many bearing clusters of maturing nuts, that have been cut off by the beetles, and twigs often accumulate in the treetops in conspicuous bunches. The cutting off of the tips of the branches reduces greatly the fruiting area of the tree for the following year and spoils the symmetry of the tree. Pecan nurseries adjacent to a badly infested territory often suffer serious losses from the girdling of the terminal shoots.

FIGURE 39.—Adult, or beetle, of the twig girdler. 3 times natural size.

SEASONAL HISTORY AND HABITS

The beetles (figs. 39 and 40) range in length from one-half to five-eighths of an inch, and are grayish brown with a broad pale belt over the back. The antennae, or feelers, are very long.

The beetles, which begin to appear in pecan orchards the last of August or early in September, girdle the branches to provide proper conditions for the development of the larvae, which are unable to subsist on wood containing sap. The cut extends through the bark and well into the wood, leaving only a small portion of the heartwood untouched (fig. 40); later the weight of the branch or the wind usually causes it to break off. The eggs are deposited in the severed portion of the twig. The larvae, which are whitish, legless grubs, make little growth during the fall or winter months, but with the return of warm weather in the spring they grow very rapidly, making tunnels in the twig. Usually only 1 year is required for development of the insect, though some larvae do not transform until the second season.

CONTROL

This pest can be controlled by gathering the severed branches and burning them in the fall or winter. Care should be exercised to collect all branches on the ground as well as those lodged in the trees. By following this procedure all eggs and larvae that would

otherwise develop into beetles the following summer will be destroyed and the source of infestation eliminated. It is also well to destroy the severed branches from the hickory and persimmon trees near commercial plantings of pecans, since the insect breeds abundantly in such locations.

PECAN CARPENTER WORM

The pecan carpenter worm (*Cossula magnifica* (Strecker)), sometimes termed "the cossid borer," tunnels the sound wood of pecan, hickory, and various species of oak, furnishing a place for rot fungi to enter. This species is known only in the Southern States and is rarely abundant.

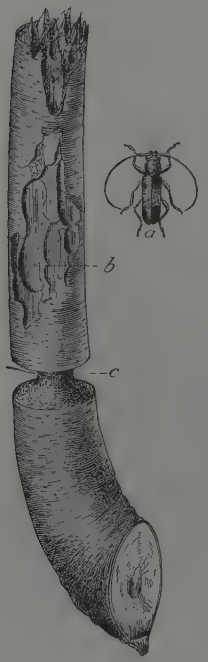

FIGURE 40.—The twig girdler: *a*, Beetle; *b*, larval mines in bark and outer wood; *c*, girdling work of adult.

Trees infested with this carpenter worm may be recognized by a pile of coarse reddish pellets at the base of the tree. In the trunk somewhere above the pile is the entrance to the larval burrow, a hole about the size of a lead pencil, closed with four tough flaps.

Eggs are laid by moths on small pecan branches in the summer. Upon hatching, the larvae bore into and mine successively larger branches (fig. 41). In the fall each half-grown larva moves down and bores into the trunk, going straight in for about 1 inch and then making another shaft 8 to 10 inches long parallel to the grain. The full-grown larva is about 1¼ inches long and has a thick, pink body and a shiny head. Late in the spring it changes to the pupa, and the moth appears in May or June.

CONTROL

The carpenter worm may be killed by injecting one medicine dropper full of carbon disulfide into its burrow and closing the hole at once with a wooden peg, moist clay, or similar material.

TERMITES

Pecan nursery stock and small trees are sometimes killed by the feeding of termites in the roots. These insects are known popularly as white ants or wood lice. They usually live in dead wood and are most likely to cause injury when pecan trees are planted on recently cleared land, containing stumps and dead roots. Affected trees may not show any indication of injury until they are damaged beyond recovery, and then they die very suddenly.

Termites (fig. 42) burrow and feed entirely away from light, and their attacks on pecan trees are underground. Pecan seedlings and budded trees 1 and 2 years old will be found with the taproot or its branches tunneled (fig. 43), sometimes only a shell or bark remaining. The feeding may extend an inch or so above the ground level inside the trunk with no evidence from the outside.

Control

When planting the nursery or orchard, care should be taken to prevent termite infestations by selecting land that is free from dead-wood. Recently cleared land should not be used for pecan until the dead roots and stumps have been removed. It is also advisable to grow annual crops on the land for 1 or 2 years before the trees are planted. Only termite-resistant stakes should be placed by newly set trees. These may be of iron, heart pine, or wood treated with creosote. Most untreated woods in contact with earth become infested with termites, and the insects then may spread to the trees.

FIGURE 41.—Larval burrow of the pecan carpenter worm in a pecan twig.

NATURAL ENEMIES OF PECAN INSECTS

If it were not for the activities of numerous enemies which prey upon the insect pests of pecan, their control would be much more difficult, if not impossible. Among these enemies are many species of birds, small mammals, spiders, and a number of insects that prey upon other insects. In the last group are such predacious insects as ground beetles, ladybird beetles, many species of stinkbugs, the larvae of syrphus flies, aphis lions, and many others that capture their prey and either consume it outright or suck the body fluids from it. Another group includes small wasplike insects and flies, which are true parasites of other insects. Most of these lay their eggs in or on their victims, the young parasites developing from these eggs living at the expense of the insects attacked and finally killing them.

A number of efforts have been made to utilize natural enemies in the control of insect pests. In a few cases the introduction of a parasite of an insect pest has been followed by a natural increase in the parasite sufficient to bring about remarkable reductions in damage. These successes, however, have been accomplished chiefly with introduced insect pests that have not been accompanied by the enemies which hold them in check in the country where they originated. Practically all the insects that are important pests of the pecan are of American origin and either attacked the pecan originally or transferred to it from some native food plant, and parasites have already had full opportunity to reach their maximum effectiveness.

During the period 1930–35 intensive investigations were carried on at Albany, Ga., with an egg parasite of the nut casebearer and several other species of pecan insects, which lays its eggs within the egg of its victim. This parasite, called *Trichogramma minutum*

Riley by the entomologists, attacks the eggs of many different kinds of insects, and is already generally present, at least in small numbers, in or near most pecan plantings. It can be propagated in enormous numbers on the eggs of the Angoumois grain moth, a common pest of stored grains. In the course of these experiments large numbers of *Trichogramma* were liberated in pecan orchards, but they gave little practical control of pecan pests.

Although further studies are being made of the natural enemies of pecan insects with the expectation of taking all possible advantage of available repressive agencies, it is unlikely that natural enemies will be found that will eliminate the necessity for spraying or the application of other control measures.

FIGURE 42.—Termites: *a*, Mature soldiers; *b*, mature workers.

DISEASES OF THE PECAN

INTRODUCTION

Diseases of pecans were of little economic importance prior to 1900, because pecan growing as an industry was new at that time. Rosette was the first disease to attract attention, but the concern it caused among growers was relieved when its noninfectious nature was experimentally established. Later scab made its appearance in commercial plantings, at first attacking only one or two important varieties. Scab is now by far the most destructive disease with which pecan growers have to contend, and it is increasing in importance from year to year. Other diseases, such as downy spot, vein spot, leaf blotch, brown leaf spot, and liver spot cause serious damage to the foliage in some localities in the southern pecan belt, whereas other diseases known as nursery leaf blight, gnomonia leaf spot, and crown gall are generally of less importance.

In recent years growers have used greater discretion in planting new orchards. Greater attention has been given to the selection of suitable sites and to the selection of varieties with regard to disease resistance. In many old orchards varieties highly susceptible to disease have been top worked to more resistant varieties. Even so, today, with the possible exception of rosette, the earlier-known pecan

diseases are more severe than formerly. Scab now attacks a greater number of varieties more severely than formerly, owing to a wider distribution of the different strains of the fungus.

The downy spot, vein spot, leaf blotch, brown leaf spot, and liver spot diseases were of only minor importance earlier, but during recent years they have assumed greater importance. Wider dissemination of the causal organisms and lack of tree vigor from crowding and neglect account for some of the diseases becoming more serious in late years.

Most fungi that cause diseases of the pecan also attack the closely related hickories, and a few organisms causing pecan diseases were first reported on hickories. It is not known whether these organisms were originally hickory or pecan parasites; nevertheless, the pecan now seems to be a favorable host of the various fungus parasites capable of attacking the hickory group of trees, of which the pecan is the most important nut producer.

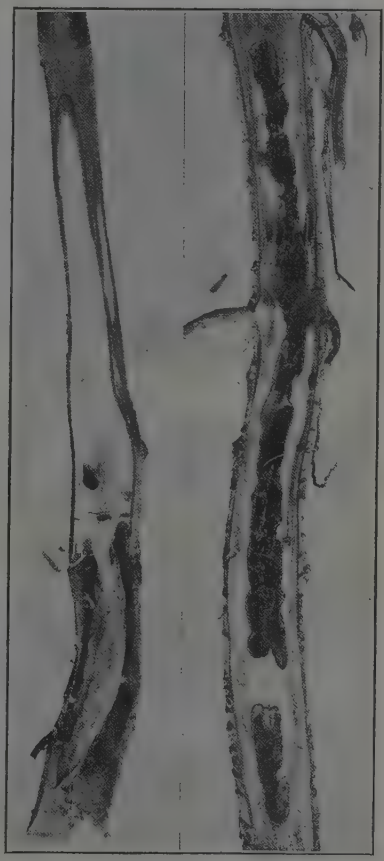

FIGURE 43.—Injury to roots of pecan nursery stock by termites.

DISEASES DUE TO SPECIFIC ORGANISMS

SCAB

The fungus causing pecan scab (*Cladosporium effusum* (Wint.) Demaree) is becoming more prevalent each year in the humid sections of the pecan-growing region and is gradually extending into the newer pecan areas where conditions are favorable for its growth. Since the disease is one of the principal limiting factors in pecan-nut production, its control is of prime importance to this new and growing industry. Some of the leading commercial varieties are highly susceptible to infection. In many localities scab annually causes a heavy loss of the crop in unsprayed orchards of some of the otherwise best commercial varieties, such as Schley, Delmas, Alley, Pabst, Van Deman, and Success. Observations and experiments indicate that there are strains or races of the pecan scab fungus, not all of them yet uniformly spread over the pecan-growing region. This explains why scab does not always attack the same varieties alike in all areas. Some varieties, such as Nelson, Teche, and Frotscher, at one time thought highly resistant or possibly im-

mune, are now known to be susceptible. It is probable that new strains of the fungus capable of attacking varieties formerly not susceptible have developed in recent years.

The fungus causing pecan scab may attack the leaves, shoots, and nuts. Infections result in elongated or circular brown or black lesions one-eighth to one-quarter of an inch in diameter. At first the spots may appear slightly raised above the surrounding host tissue, but later may be sunken, especially on the twigs and nuts. Spots

FIGURE 44.—Pecan scab on leaf, shoot, and nut.

that appear as the tissues age are fewer, smaller, and more nearly circular than those occurring early in the season. The lesions occur chiefly along the veins of the leaves, and the earliest on the nuts occur along the ridges (fig. 44). If abundant, the spots on the nuts may unite and form irregular black blotches or become so numerous as to blacken the entire surface. Severely infected nuts may drop prematurely, or they may die and remain attached to the shoots for several months.

Frequent April rains and cloudy weather favor early spring infections. Under such conditions, initial infection may occur prior to the middle of April in the latitude of southern Georgia. The primary lesions produce copious new crops of spores as favorable weather conditions happen, and by the latter part of April or the first week in May many secondary infections take place. The young leaves are extremely susceptible to infection while they are unfolding and developing but become more resistant as they grow older. As soon as the leaves are fully grown and have taken on a dark-green color, they are highly resistant. The nuts are susceptible until almost fully grown, but only the tender, vigorously growing portions of the new shoots are subject to attack.

The fungus is carried over from one season to another in the lesions on shoots, shucks, and leaf stems. Under favorable weather conditions in April and May, the dormant fungus within the last year's scab spots becomes active and produces spores that infect the new leaves, shoots, and nuts.

Rainy periods or late afternoon rains which keep the leaves and nuts wet continuously for 12 to 18 hours make a condition very favorable for germination of the spores and infection of the plant tissues. Dew may also bring about this condition; it is important at least in spreading the spores from a lesion to healthy tissue. Leaves and nuts must be wet over a period of 4 to 6 hours for infection to take place; therefore, short showers followed by sunshine seldom cause any spread. A period of 6 to 10 days elapses from the time the spores germinate, through infection of the tissues, to the first visible evidence of the scab spots.

Distribution and Economic Importance

Pecan scab is widely distributed throughout the Southern States. It was first found on hickory in southern Illinois and has since been reported from Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Tennessee, Arkansas, Texas, and Oklahoma. The disease causes most damage in the territory embracing northern Florida and the southern portions of Georgia, Alabama, Mississippi, and Louisiana. In this region the disease not only attains its greatest degree of destructiveness but also attacks a greater number of varieties than elsewhere. In the northern half of Georgia, Alabama, Mississippi, Louisiana, and eastern Texas the disease has not yet become serious except on a few very susceptible varieties, and it is rarely found in the drier parts of Texas. The fungus does not thrive so well in the more northern and western pecan districts as along the coast because of less frequent rains, lower humidity, and sparse plantings.

Most varieties are susceptible to scab; but in a section where the fungus thrives, infection depends on whether or not there is a strain or race of the fungus capable of attacking the variety grown. Susceptible varieties may appear immune for a limited period in isolated orchards, or even over extensive areas, and later succumb to the disease when a suitable strain of the causal organism is introduced and becomes established. The various strains are becoming more uniformly distributed in areas where weather conditions favor the development and propagation of the fungus.

Methods of Control

SPRAYING

A large number of spray materials, including home-made and proprietary compounds of sulfur and copper, have been used in pecan scab control experiments during the past 20 years. Lime-sulfur solution and other compounds of sulfur have given good results in moderately infected orchards or when used during seasons of light rainfall but have proved ineffective when infection has been severe. Home-made bordeaux mixture is the most effective and dependable fungicide so far tried. It is made of copper sulfate, hydrated lime, and water. A 4–1–100 bordeaux mixture—4 pounds of copper sulfate, 1 pound of hydrated lime, 100 gallons of water—applied early in the season when the catkins are appearing and the first leaves are about one-half grown, followed with three or four applications of 6–2–100 bordeaux mixture, has been recently suggested as the standard spray to combat scab and other fungus diseases of the pecan. (See spray program, p. 70, for time of application and complete spray schedule.)

Spraying can be done earlier than was previously recommended without undue injury to the young foliage or to the pollen, provided a weak mixture is used. There is a distinct advantage in spraying early, because the foliage and shoots when young are in the most susceptible stage for infection. If they can be effectively protected, much of the primary infection is prevented from which secondary infections spread to the leaves and nuts.

In spraying to control scab the first two applications are most important in protecting the new shoot growth and the upper and lower surfaces of the new leaves from infection. Unless scab is poorly controlled, the shoots should be relatively free from scab lesions after the first season of spraying, thereby reducing sources of inoculum most effective in starting the earliest spring infections. When there are no shoot lesions to contend with, it should be much easier to control scab by following the program of sanitation and spraying recommended.

The third and fourth applications are most important in protecting the nuts against infection, because by the time they are made the first leaves will have matured enough to be resistant to scab. However, besides scab, there are usually aphids, leaf spots, or the leaf casebearer to control with these applications, so the leaves will have to be sprayed as thoroughly as with the first two applications.

Although bordeaux mixture furnishes pecan foliage and nuts with by far the best protection against infection by the scab organism of any fungicide tried, the fact must not be overlooked that the spray may have two undesirable effects upon pecan foliage.

(1) Applications of bordeaux mixture on pecan trees during midsummer in most sections of the southern pecan belt are followed by an increase in the population of black pecan aphid. The aphids may increase to the extent that it is necessary to include nicotine sulfate with the bordeaux mixture to avoid serious foliage injury from them. (For information about combating the black pecan aphid, see p. 18.)

(2) Serious injury, characterized by burning or yellowing and dropping of the leaves, sometimes has occurred when bordeaux mix-

ture has been used during periods of soil-moisture deficiency. Applications of bordeaux mixture during periods of dry weather seem to accentuate injury from drought. It is also true that fungi do not thrive well under dry conditions. Therefore, under droughty conditions, it is best to discontinue spraying with bordeaux mixture at least until rain threatens.

ORCHARD SANITATION

Orchard sanitation in pecan-disease control has for its objective the disposal of all overwintering sources of fungus inoculum as completely as possible, in order to prevent early leaf spotting the following season.

FIGURE 45.—The previous year's infected shucks often remain attached to the shoots over winter and become a source of inoculum for the young leaves the following spring. Note the scab lesions on the young leaves nearby. Photographed April 27, 1937.

The scab fungus lives through the winter in infected shoots, shucks, and leaf stems. Frequently the infected shucks of the previous year cling to the shoots all winter; the old lesions bear spores and become important sources of inoculum early the following spring (fig. 45). All such shucks should be removed from the trees before the beginning of the growing season, as they are potential sources of inoculum. Fungi that cause the various leaf spot diseases, such as vein spot, blotch, liver spot, and others, live over winter in the old diseased leaves, and the importance of disposing of such infected material cannot be over emphasized.

An effective method of disposing of the fallen shucks, leaves, and leaf stems is to plow them under with a turnplow, which places the infected material so deeply beneath the surface that it is not dragged out by later cultivation. Some growers who own or control extensive acreages of pecans claim that it is not practical to use the turnplow; they use instead the disk harrow, which will cover most of the debris. Winter cover crops growing in an orchard will necessitate altering the sanitation methods suggested, as undoubtedly it will be more ad-

vantageous to tree growth and nut production to allow the cover crop to grow to maturity than to plow it under earlier on account of sanitation purposes.

If the sanitation methods are to be effective, the early plowing or disking should be completed early in March before the opening of the leaf buds. To lessen the scattering of spores from the infective material during the period that the young leaves are specially susceptible, further cultivation should be discontinued until after the leaves are protected with the second application of spray material. If harvesting from diseased trees is done on sheets, much inoculum can be eliminated by removing from the orchard the old leaves and shucks that fall on these sheets.

There is no known method of destroying the overwintering scab fungus on the shoots. Dormant sprays of strong solutions of copper sulfate and lime-sulfur have been tried with little or no success. Summer spraying with bordeaux mixture, however, will largely prevent shoot infection.

Relative Susceptibility to Scab of Commercial Varieties of Pecan

More than half of the commercially important varieties of the pecan planted within the region of the most frequent rains, i. e., a narrow belt along the Gulf coast about 50 miles wide from Lafayette, La., to Tallahassee, Fla., can be classified as very susceptible to scab infection.

North of the Gulf coast area a lesser number of varieties are at present attacked. In this area, generally, the most susceptible are Delmas, Georgia, Schley, Alley, and Pabst. High humidity and frequent rains are apparently not the only factors that influence the endemic nature of the disease; others, such as the preponderance of certain varieties in a locality, time and length of rainy period, the presence of suitable strains or races of the scab fungus, age and size of orchards, and distance between orchards play important parts in favoring the prevalence of the disease.

The following is a list of the most generally known pecan varieties listed in the order of their susceptibility to scab from very susceptible to resistant: Delmas, Halbert, Georgia, Burkett, Schley, Alley, Pabst, Van Deman, Success, Frotscher, Moneymaker, Mobile, Moore, Nelson, Curtis, Teche, and Stuart.

DOWNY SPOT

Downy spot (*Mycosphaerella caryigena* (Ell. and Ev.) Demaree and Cole) is a leaf disease of pecan widely distributed throughout the southern pecan belt. It first appears during the latter part of May or the first of June as white or downy spots on the lower side of the leaves. The white spots are composed of innumerable small spores or conidia of the causal fungus (fig. 46, A). The spores are readily washed away by rains, leaving inconspicuous greenish-yellow spots about one-eighth of an inch in diameter. The affected leaf tissues do not die until the latter half of the summer, when the spots change to brown (fig. 46, B); the spots may then be seen on the upper side of the leaves. There is considerable variation as to the susceptibility of different varieties to attack by the fungus. Of the common commercial varieties, Delmas, Moneymaker, Stuart, and Frotscher are the most readily attacked.

The fungus causing downy spot lives over winter in the diseased leaves from the previous year. The spores are expelled by the fruiting bodies of the fungus during rainy periods in March, April, and May, at which time the young leaves are infected, but the first evidence of the disease does not begin to show plainly until a month or 6 weeks later.

Control

Inasmuch as the spores of the causal organism may be liberated during the period of rapid foliage development in April, a spray

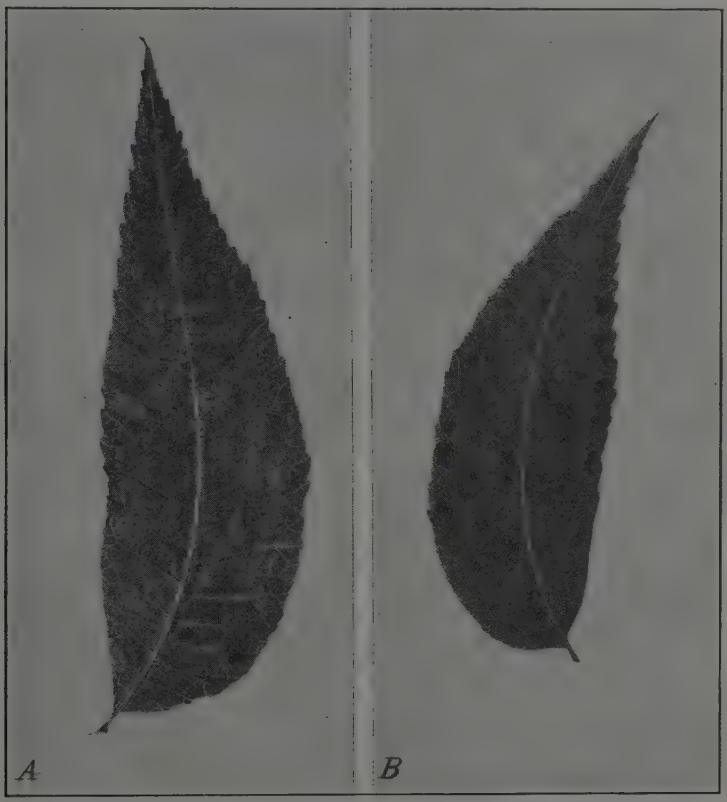

Figure 46.—Downy spot of the pecan: *A*, In the early stage of the disease the markings are white, caused by the presence of innumerable white spores; *B*, in the latter half of the summer the spots change to a brown color.

should be applied some time during that period to furnish the maximum protection. One application of 4–1–100 bordeaux mixture made in the early spring before pollination, followed by an application of 6–2–100 bordeaux mixture between the middle of May and the middle of June, will prevent the downy spot disease.

VEIN SPOT

Vein spot (*Gnomonia nerviseda* Cole) and liver spot are two diseases of pecans commonly found in the southwestern but not in the southeastern section of the pecan belt. Both diseases are prevalent in Texas, Louisiana, Arkansas, and Mississippi, but vein spot ranges farther south than liver spot. (For description of liver spot see p. 48.)

The resemblance of vein spot to scab lesions on the leaves is so striking that the two diseases are easily confused. The spots characterizing both diseases are dark brown or black in the final stage, and both originate on veins. The lesions of the vein spot disease are of two shapes; spots originating on the very small veins are circular or oval and seldom attain a diameter of over one-fourth of an inch; spots found on the larger veins and leaf stems are long and narrow, sometimes extending from the base to the apex of a leaflet. The fungus apparently invades the leaf tissues only a short distance on each side of the vein, except that it has a tendency to follow the lateral veins a short distance from the infected larger ones (fig. 47).

If the petiole or rachis of the leaf is severely affected, the leaflets and frequently the whole leaf drop prematurely or the petioles of the leaflets become girdled causing the leaflets to die and hang on the tree for a time. The fungus is aggressive and attacks vital tissues of the leaves; premature defoliation follows moderate to severe infection. The Van Deman, Frotscher, and Stuart varieties appear to be more subject to the disease than are many other commercially important varieties.

The life history of the fungus causing the vein spot disease is similar to that of most other fungus parasites of pecan foliage. It lives through the winter on the fallen leaves and forms spores that are discharged into the air during early spring, and the new leaves are inoculated during April.

CONTROL

Vein spot usually can be controlled commercially by spraying once before pollination with bordeaux mixture 4–1–100, followed by one or two additional applications of bordeaux 6–2–100. The second application should be made as soon after pollination as possible and the third 3 weeks later. For the present it is recommended that the same orchard sanitation and black pecan aphid control be followed as discussed under pecan scab (p. 40).

LEAF BLOTCH

Leaf blotch (*Mycosphaerella dendroides* (Cke.) Demaree and Cole) is a disease of pecan foliage that was first observed in 1923. Gradually extending its range of distribution, it is now found in practically every pecan nursery and orchard in northern Florida and the southern part of Georgia, Alabama, Mississippi, Louisiana, and eastern Texas. The first conspicuous sign of leaf blotch is the appearance of brown or greenish-brown velvety tufts of spores on the under surface and faint yellowish spots on the upper surface of the leaves. Somewhat later small pimplelike structures appear among the tufts

of spores and often extend beyond their limits. The spores are washed away by rains, leaving the clusters of innumerable small black pimplelike structures as the only signs of the disease.

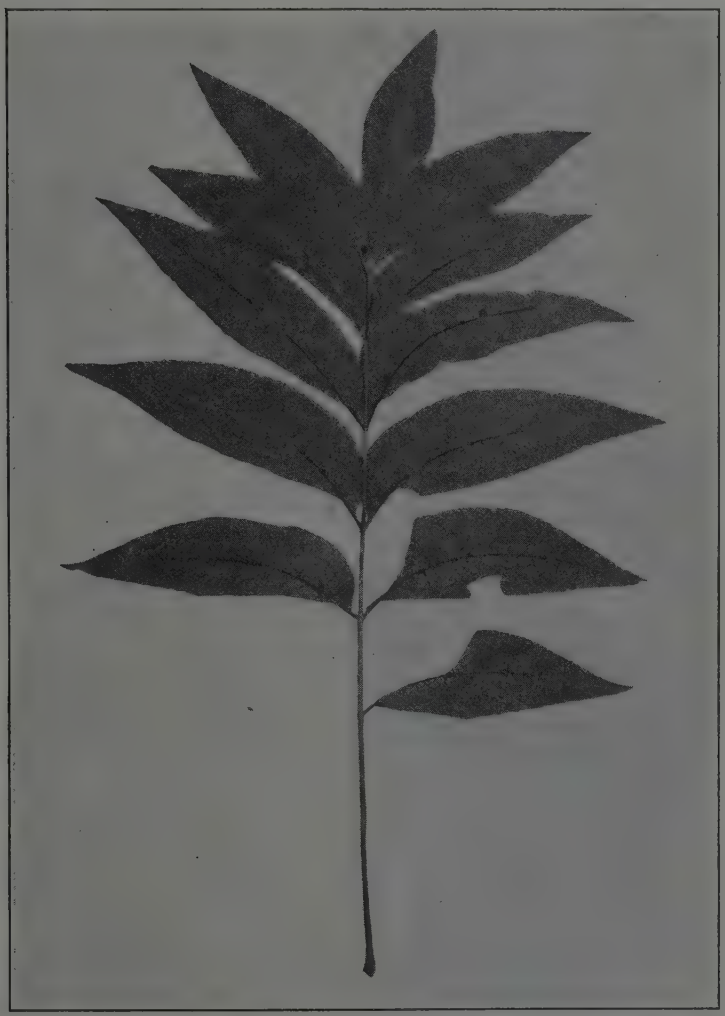

FIGURE 47.—Characteristic appearance of a pecan leaf attacked by the vein spot fungus. The discoloration is confined strictly to the midribs and veins of the leaflets and to the petiole.

These small, black, pycnidial structures usually are arranged in groups or clusters of various sizes ranging from that of a pinhead to one-quarter inch or more in diameter. Less frequently they are scat-

tered. The spots may be few in number on a leaflet, but more frequently they are numerous and crowded and coalesce to form large blotches that may involve a large portion or the entire leaf surface (fig. 48).

FIGURE 48.—Pecan leaf blotch. During this stage the spots are made up of many small black pimplelike bodies.

The disease is first found in late June or early July on the older leaflets and may gradually increase until all mature leaves are spotted or killed. On nursery trees the disease first appears on the lower leaves, but as the season advances the upper leaves are also attacked. Defoliation follows severe attacks and progresses from the lower branches upward until the first of November, when only a few of the youngest leaves remain. Within its geographical range, blotch is often the most prevalent of the foliage diseases on orchard and nursery trees and causes much premature defoliation.

CONTROL

The blotch pathogene is a weak parasite and does not readily attack young or vigorous orchard trees or older trees that are growing in fertile soil and are given cultivation. Trees lowered in vigor from too keen competition for water, nitrogen, and other food-forming elements are more severely attacked by the disease. Overcrowding or neglect, and allowing weeds, grass, and brambles to overrun the orchard predispose the trees to this disease. In such crowded, neglected, or poorly cared for orchards the disease spreads rapidly, and by the middle of August the efficiency of the foliage is impaired and a month or 6 weeks later is totally destroyed. Badly affected trees may lose their leaves early. Without foliage they are unable to manufacture sufficient food materials to fill the nuts properly and to build up the reserve necessary to set a crop the following year.

The blotch disease is easily controlled. One or two applications of bordeaux mixture in May and June will furnish protection for the foliage for the remainder of the season.

BROWN LEAF SPOT

Brown leaf spot (*Cercospora fusca* (Heald and Wolf) Rand) is one of the most common leaf diseases of the pecan and is distributed throughout the pecan belt. A pecan leaf with the characteristic markings of brown leaf spot is shown in figure 49. The spots have circular to irregular outlines and vary from one-eighth to one-half inch across. They are usually reddish brown, but the older spots often become grayish and develop concentric zones.

This disease rarely appears before the first of July, and only mature leaves are readily attacked. The spots may increase in number rapidly after midseason, and frequently cause total defoliation by the first of October.

Although the Stuart and Moneymaker varieties are among the most susceptible of those commonly grown, no variety has proved to be immune or highly resistant when the orchard is subjected to adverse growing conditions. Like blotch, the fungus of brown leaf spot often becomes established in orchards where the trees are low in vigor. Foliage of trees badly affected with rosette is frequently spotted with the brown leaf spot disease. When rosette is overcome on badly affected trees by treatment with zinc sulfate, then leaf diseases such as brown leaf spot or blotch becomes less prevalent or disappear entirely.

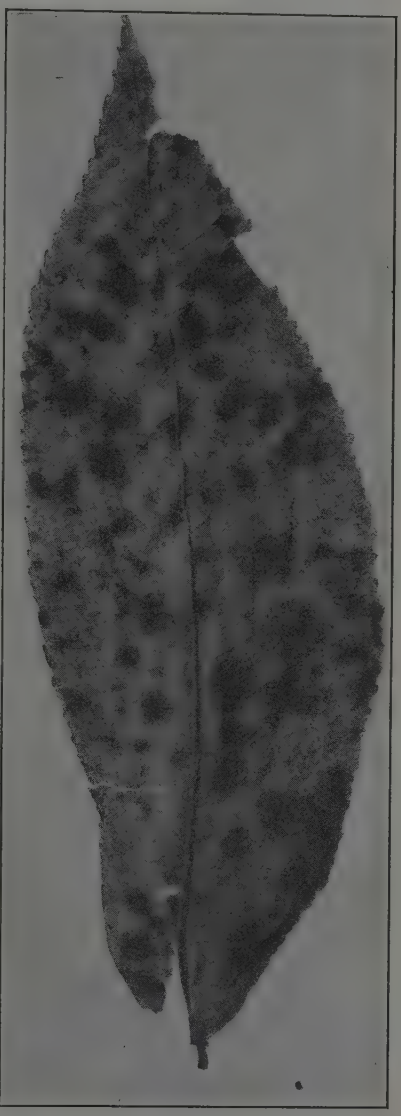

FIGURE 49.—Brown leaf spot of pecan.

Control

Young, vigorous pecan orchard trees, especially if on good soil and cultivated, seldom if ever become badly diseased with brown leaf spot.

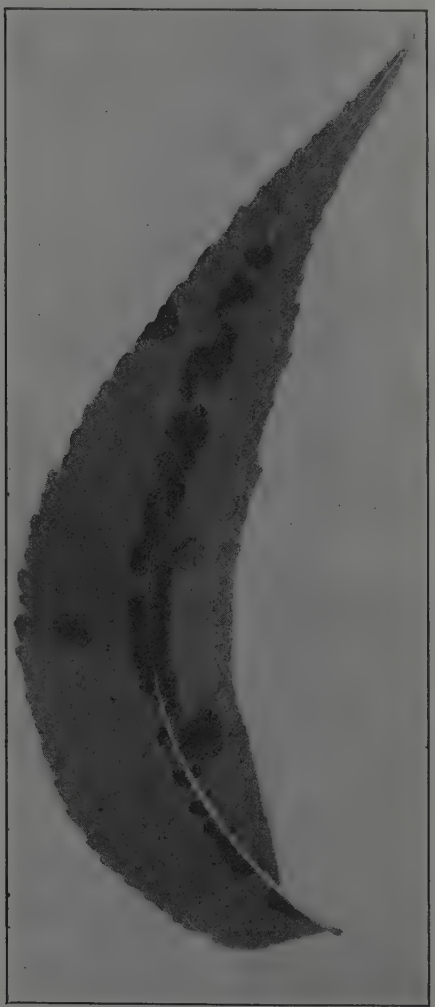

FIGURE 50.—Pecan leaflet showing early stages of liver spot.

The disease can be controlled easily. One application of bordeaux mixture any time during May, June, or July will effect good control. The best protection is obtained when the spray is applied about the middle of June.

LIVER SPOT

Some years a disease known as liver spot, caused by *Gnomonia caryae* Wolf var. *pecanae* Cole, does considerable damage to pecan foliage in central Mississippi, the northern half of Louisiana, southern Arkansas, and eastern and central Texas. The disease first appears during May and June as dark brown circular spots one-eighth to three-eighths of an inch in diameter on the lower surface of the leaflets and mainly along each side of the midrib (fig. 50). In September and October the color of the spots changes from a tan to cinnamon brown, and at about the same time small, dark, spore-bearing bodies appear in the center of the spots. Leaflets having several spots will fall during September or October. During seasons when weather conditions are favorable for numerous infections, severe premature defoliation occurs.

The fungus causing the liver spot disease survives in a semidormant condition during the winter months on the fallen leaves, but upon return of moist warm weather in the spring it renews activity and produces

a new crop of spores, which inoculate leaves of the current year's growth.

The foliage of strong, vigorous trees is noticeably more resistant to attack than that of trees whose vigor has been impaired by the weakening influence of keen competition by weeds and grasses for moisture and nitrogen.

Control

The disease may easily be prevented by the use of a good fungicide. One application of bordeaux mixture, 6–2–100, any time during May, preferably after the middle of the month, will furnish very satisfactory protection to the foliage.

POWDERY MILDEW

The powdery mildew fungus, *Microsphaeria alni* (Wallr.) Wint., forms a white superficial growth on both leaves and nuts of the pecan. It appears during May, June, and July, especially in seasons of considerable rainfall and high humidity. Because of its habit of coating the leaves and nuts with a white powdery growth, it frequently causes growers some concern. Usually infected nuts develop normally without evidence of injury, but occasionally damage is done to the most susceptible variety and seedling trees in the Piedmont section of Georgia. Severe attacks that result in a reduced size of nuts and shriveled kernels are comparatively rare. The Pabst is the most susceptible of any of the more commonly grown varieties.

Control

Control measures are seldom necessary. The disease has never been known to appear in an orchard where a fungicidal spray has been used to prevent other diseases. A spray applied when the mildew first appears will prevent further spread.

NURSERY BLIGHT

Pecan nursery blight, caused by *Sphaceloma* sp., is a leaf disease of young nursery trees and rarely occurs in orchards. It is widely distributed throughout the southern portion of the pecan belt and is of considerable economic importance in pecan nurseries in wet seasons, when it causes severe defoliation. Pecan seedlings badly affected with nursery blight make little growth and sometimes are too small for budding at the end of the second year's growth when most trees should be large enough to bud.

The disease first appears in April as small reddish spots on both sides of the leaves; later, the color of the spots on the upper surface turns gray. Spots are most abundant along the veins or the margins of the leaves. The dead leaf tissues become brittle and break out, leaving irregular ragged margins and perforations (fig. 51). Single spots are seldom more than one-eighth of an inch in diameter, but two or more spots may unite. Although late-season infections may occur at any point on the upper surface, they are most com-

monly found along the midribs and larger veins, as illustrated in figure 52.

Control

Nurserymen who spray to control this disease make four or five applications of bordeaux mixture at intervals of 3 or 4 weeks. The first application should be made soon after the first leaves have formed and before infections have begun.

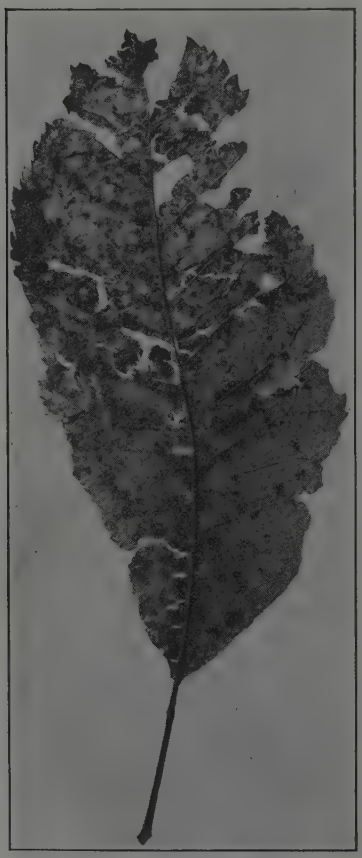

Figure 51.—Nursery blight on young pecan leaflet.

Gnomonia Leaf Spot

The gnomonia leaf spot (*Gnomonia dispora* Demaree and Cole) is another pecan disease of minor importance occasionally observed in Florida and the southern part of Georgia. It first appears in June as a small, inconspicuous brown spot with no certain diagnostic features. The spots may enlarge to one-half inch or more in diameter and become almost black. The shape of the spots varies from circular to greatly elongated. The most distinguishing characteristic of the gnomonia leaf spot is that affected areas are frequently confined to a narrow space between the lateral veinlets, forming a long, narrow, dead area (fig. 53). The disease has not become serious enough to justify the use of control measures. So far it has been found only on rosetted trees, which suggests that the fungus causing the spots is a weak parasite.

Wood Rots

Wounds made in top-working and pruning pecan trees and those from other causes, such as careless cultivation, winter injury, sun scald, and windstorms, are all possible points of entrance for wood-rotting fungi. The hot, humid climate of the Southern States favors the rapid development of these fungi, and unless wounds are protected from infection and cared for so as to aid healing, it is very probable that fungi will gain entrance and endanger the life of the entire tree.

Stubs should not be left in pruning; wounds should be made flush with main branches or the body of the tree to allow the wounds to

heal more quickly (fig. 54). Care should be taken in removing limbs not to allow them to split or to tear the bark. This danger will be avoided if the branch is cut nearly half through from the under side first and then finished from above. An alternative is to saw the limb off, leaving a stub, and then remove the stub.

Entrance of wood-rotting fungi into wounds can usually be prevented by painting the cut surfaces carefully and thoroughly with some antiseptic tree-wound dressing. There are several tree-wound paints, dressings, or protectives sold under various trade names that may be purchased, most of which have asphalt, tar, or vegetable gum as their base. A home-made paint used extensively on pecan with good results is made of 1 part of commercial creosote to 3 or 4 parts of coal tar. The creosote in this compound may cause slight injury to the cambium. The injury can be prevented by first painting the outer edge of the wound or cut surface with a band of shellac so as to cover the bark, cambium, and the adjoining sapwood. The wound should be painted immediately after it is made, unless sap is flowing, and repainted annually thereafter until completely healed.[3]

FIGURE 52.—Pecan nursery blight as it often appears on mature leaflets.

CROWN GALL

Crown gall (*Bacterium tumefaciens* Smith and Town.), as the name implies, is primarily a disease causing enlargements on the lower extremity of the trunk or roots at or below the ground line. A typical specimen of crown gall is illustrated in figure 55. Crown gall has been considered of minor importance, because galls have not been commonly seen. Orchards in widely separated areas are known to be badly infected, and many

[3] For further information on treatment of tree wounds, see Farmers' Bulletin 1726, Treatment and Care of Tree Wounds.

trees in those orchards have extremely large galls that doubtless do damage. The disease is most commonly seen on young trees as they are dug from the nursery. Nursery trees should be inspected before planting, and those having definite galls should be discarded and burned. The disease may be spread from diseased to healthy trees by means of cultivating and propagating tools. Therefore, trees should not be scarred with harrows or the galls cut into with budding or grafting knives.

DISEASES DUE TO NUTRITIONAL OR ENVIRONMENTAL FACTORS

ROSETTE

In its earliest stages, or on slightly affected trees, rosette is indicated by a slight yellowish mottling of the leaves, particularly in

FIGURE 53.—Gnomonia leaf spot on pecan. Delimitation of the spots by the leaflet veins is characteristic of the disease.

the tops of the trees. In more advanced stages the leaflets are slightly narrowed and crinkled. When the trees are severely affected the leaflets are extremely narrowed, with either reddish-brown areas or perforations between the veins. New shoot growth is checked, the internodes are shortened, and the foliage is bunched, resulting in a rosetted appearance. The name of the disease is derived from this characteristic. In the final stages of the disease the shoots die back from the tips. Usually the dying back is confined to the current year's growth but sometimes extends to branches of considerable size. Seriously affected trees rarely bear nuts, and those borne may be small. The early spring foliage on badly rosetted trees is often abnormally large and develops earlier in the spring than the foliage of normal

trees, probably because of the pruning effects of the dieback. Symptoms of the disease on moderately or badly affected trees become more pronounced as the season advances, and by October or November the trees appear at their worst. The foliage of affected trees in the more advanced stages has a rusty or bronzed appearance, especially when viewed from a distance.

All varieties and wild seedlings will show the disease if they are growing on certain types of soil, especially if under cultivation. The Stuart, Van Deman, Frotscher, and Delmas are perhaps the most susceptible. Of the varieties resistant to rosette only the Moneymaker is of outstanding merit.

The disease is found in all pecan-growing States from Maryland to California. Trees affected with rosette are rarely found in the unthinned native pecan forests along the rivers in Texas and Louisiana, but the disease frequently occurs, and usually in a very serious form, when these native stands are thinned and put in cultivation. The disease also frequently occurs in orchards in the calcareous upland soils of these States.

FIGURE 54.—Wound made by removal of a large limb. Such wounds heal more readily if the cut is made almost flush with the trunk.

For many years it has been suspected that pecan rosette was associated in some way with soil conditions and orchard practices. The following soil conditions are most commonly associated with rosette: Calcareous soils, sandy loam, loamy sand, and deep sandy soils extremely deficient in organic matter; eroded soils having little or no surface soil remaining, and relatively fertile soils that have received deep and frequent cultivations or excessive applications of fertilizers, especially nitrogen, or of lime. A large percentage of rosetted trees are found in young orchards ranging between the ages of 5 and 15 years which are

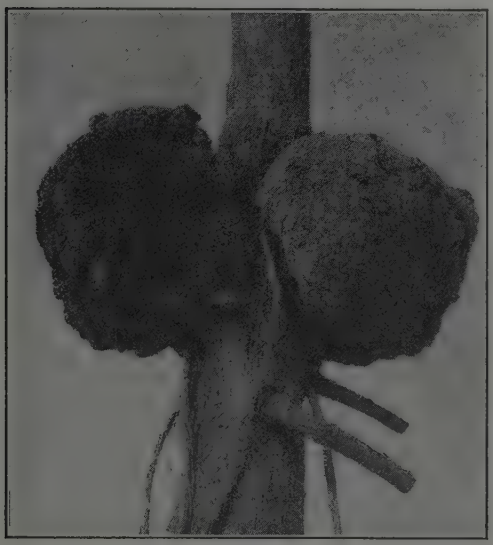

FIGURE 55.—Crown galls on pecan nursery tree.

intercropped annually to cotton, corn, or peanuts. There is also an association of widespread but temporary appearance of rosette following droughts.

There are comparatively few orchards entirely free from the rosette disease. Those that are, grow in deep, loamy, uniform soils, or are those used as pastures.

Treatment With Zinc Sulfate

On soils readily susceptible to improvement rosette may be remedied, but slowly, by consistently following an orchard-management program that includes: (1) Turning under cover crops annually, or adding other organic matter such as manure, leafmold, swamp mulch, or cane pomace; and (2) limiting the amount and depth of cultivation to that necessary to keep down weed growth, and to prepare a seedbed for planting cover crops.

Although the fundamental cause of rosette is not definitely known, recent investigations indicate that the disease is in some manner closely associated with a deficiency of zinc in the affected trees. Zinc, in the form of zinc sulfate, supplied in such a way that rosetted trees absorb it, results in a prompt improvement. This new treatment gives promise at the present time of providing pecan growers with a cheap and quick method of entirely eliminating this disease from their orchards.

Three methods of applying the zinc sulfate have been tried and found effective.

soil application

The application of zinc sulfate to the soil around rosetted trees is effective principally on trees growing in neutral, acid, and sandy alkaline soils. Trees growing on heavy textured soils that are alkaline or have a high fixing power for zinc may not respond to applications of zinc sulfate made to the soil. Therefore, in general, rosetted pecan trees growing on soils having a high fixing power for zinc will respond more quickly and probably more satisfactorily if treated with zinc sulfate either by spraying or by inserting the dry material into the tree trunks. Although rosetted trees in acid soils respond to the spraying and injecting methods, they also respond readily to soil applications of zinc sulfate applied with or in the same manner as fertilizers. Applications to the soil seem to have the most lasting effects and are most generally used on acid soils. The first cost of material, however, is more than for either spraying or the dry-salt-injection method because more material is used.

On soils not having a high fixing power for the zinc the rate of application should be ½ to 1 pound of zinc sulfate for each year of the tree's age, or from 1 to 2 pounds for each inch of the diameter of the tree trunk. The larger the dosage the greater will be the improvement from the diseased condition the first year. When used as a fertilizer the zinc sulfate should be applied in late February or early March. Furthermore, it should be broadcast evenly beneath the trees, from near the trunk to beyond the limb spread. Quicker and more positive results will probably be obtained by disking or plowing the zinc sulfate into the soil, especially on steep slopes that may wash, or on alkaline soils where the zinc may be fixed in the surface soil, or when there is not sufficient moisture to dissolve the salt and carry it down into contact with the absorbing roots.

DRY SALT INSERTION

This treatment must be given pecan trees in late winter or early spring before the sap begins to flow. To treat the trees, holes seven-sixteenths of an inch in diameter and 2½ to 3 inches deep are bored at intervals of from 4 to 6 inches spirally once around the circumference of the tree trunk. The bottoms of the holes should be somewhat lower than the opening. In each of these holes 1 heaping teaspoonful (one-third of an ounce) of dry zinc sulfate is inserted. A tube or funnel made of tin should be used to convey the zinc sulfate into the holes so that none of the salt comes in contact with the cambium. The holes are then plugged with No. 4 cork stoppers so driven into the hole that the outer edge of the cork is even with the cambium of the tree trunk. This method of treatment is recommended only when soil applications of zinc sulfate are known to be ineffective or when the trees cannot be sprayed. In some cases this method of treating rosetted pecan trees has caused some injury to the tree trunks by killing the wood and bark adjacent to the holes. Consistent and complete recovery from the disease does not always follow this method of treatment because of the small amount of zinc used. Furthermore, trees which have recovered from rosette as a result of this treatment do not usually remain free from the disease for more than 2 or 3 years.

SPRAY APPLICATIONS

To control rosette by spraying, the trees must be sprayed with a solution of zinc sulfate, and the first spray must be applied before the disease appears in the spring. The solution is made by dissolving 2 or 4 pounds of zinc sulfate in 100 gallons of water. The stronger solution will sometimes cause slight to moderate injury to the foliage, but the recovery from the disease is quicker when the stronger solution is used.

The first spray should be applied from 3 to 4 weeks after the trees begin to leaf out in the spring. The second and third applications should be made at intervals of 3 weeks, the same solution being used as in the first spray. It may be advisable to make a fourth application, 3 to 4 weeks after the third, on young trees that continue growth late in the season. It is important in applying zinc sulfate solution that all the leaves on the trees are thoroughly covered with the solution. The spray outfit should be thoroughly flushed out with clean water after each usage to prevent injury to the machine.

In orchards showing rosette where the complete scab control program is followed the zinc sulfate may be combined with the bordeaux mixture in the cover sprays. However, 4 pounds of zinc sulfate should be used in 100 gallons of bordeaux mixture, since the excess lime will precipitate out some of the zinc.

The method of treatment selected by each individual grower will be governed by his equipment and means, also by the type and reaction of his soil. Spraying will furnish the quickest and most striking effect of any of the three methods (figs. 56 and 57), but this treatment is not permanent and will require repeating annually for several years. Spraying is a comparatively cheap method of rosette treatment provided the grower has a spray machine. The trunk insertion method of treatment is the cheapest and most adaptable of any, but

the effect of trunk treatments will probably not last longer than 3 years. Furthermore, the injury resulting from holes in the tree trunk, though perhaps not severe, should not be ignored.

Fundamentally the soil method of treatment seems to be the most practical and permanent on soils where the trees respond to its use,

FIGURE 56.—A typical badly rosetted pecan tree. Photograph taken May 2. Figure 57 shows the same tree on October 11 after it had been sprayed three times with zinc sulfate solution.

and one application of a sufficient amount will be effective for several years. Rosetted trees should react to soil treatments until the zinc compound has been used by the tree, leached away, or become otherwise unavailable for use.

FORMS OF ZINC SULFATE

Commercial zinc sulfate is offered for sale in two forms which may vary in composition according to the amount of water of crystallization contained in the salt; the monohydrate zinc sulfate, usually a

FIGURE 57.—The same pecan tree shown in figure 56 after having been sprayed April 27, May 21, and June 25 with zinc sulfate solution. Photograph taken October 11.

granular material containing about 36 percent of zinc, and the pentahydrate usually in the form of small flakes containing about 25 percent of zinc. Both compounds are usually effective in the control of

rosette when used in equivalent amounts. The concentrations of spray solutions and rates of applications recommended are based on the use of the pentahydrate form. The amount of zinc sulfate may be reduced one-third if the monohydrate form is used.

LITTLE LEAF

In the more pronounced cases of pecan little leaf the leaflets fail to develop to normal size, the length and width being reduced to about one-third or one-half of an inch. The leaf itself is often reduced to a length of only 1 to 2 inches, exclusive of the petiole or leaf stem.

FIGURE 58.—Little leaf disease of pecan.

A slightly affected leaflet may be normal in size, the only visible symptom of the disease being the blunt point (fig. 58). Some trees observed have been so severely affected that all their leaves were composed of leaflets of the extremely rounded and dwarfed type. On some trees the disease may be found only on certain branches, whereas other limbs produce normal leaves and twigs. Badly affected trees do not bear nuts, and their growth is greatly retarded. Considerable

evidence indicates that some trees recover after one or more years, whereas it is definitely known that the trouble has persisted in others for a number of years.

This disease is of minor importance, as it seldom occurs under orchard conditions. When found, the diseased trees are usually

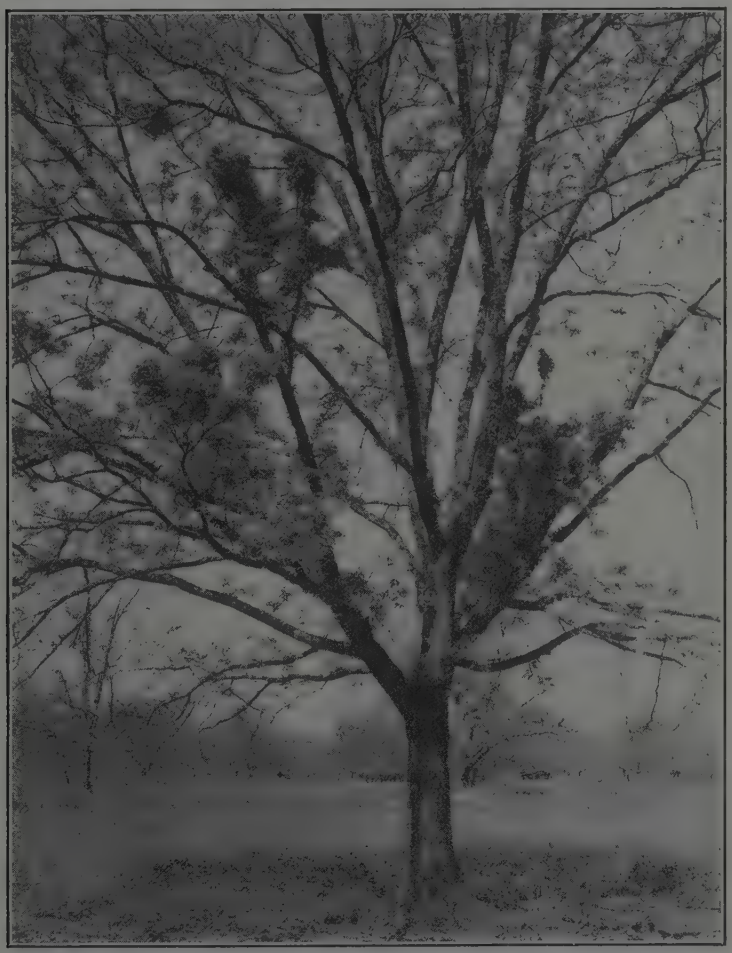

FIGURE 59.—A pecan tree showing the bunch disease as it sometimes appears early in the spring.

growing in city gardens and lawns. It has been seen in a number of States bordering the Atlantic and Gulf coasts from North Carolina to Mississippi. The cause of the disease is not known and consequently no remedy can be suggested.

BUNCH DISEASE OR WITCHES'-BROOM

The characteristic symptom of bunch disease is a bushy or broomy growth of slender, willowy twigs resulting from an abnormal forcing into growth of lateral buds. In lightly affected trees, portions of

FIGURE 60.—Clumps of compact willowy growth caused by the bunch disease, as seen under winter conditions.

one or of several scattered branches may be affected (fig. 59). The bunch growths are most conspicuous in the spring because of the compact, rapidly growing foliage and in early summer when affected parts are continuing their growth in contrast to the unaffected parts of the tree (fig. 60). Badly affected trees are merely worthless

skeletons of main lateral branches covered with a thick, broomy sucker growth. Many leaflets on diseased growth die and fall in late summer or early autumn, there is some death of shoots and branches, and yields of nuts from affected trees are little or nothing. Symptoms of bunch disease spread slowly through a tree, several years being required for a large branch to become entirely involved after the first evidence appears; often growths arising from the crown of the tree or at a graft union appear not to spread for several years. Without close observation bunch disease may easily be confused with rosette, but the leaflets on growth affected with bunch disease do not take on the yellowing between the veins or the extreme crinkliness characteristic of rosette. This disease may also be mistaken for little leaf.

The disease has been observed in a number of named pecan varieties, as well as in wild seedlings. Varieties show some difference in susceptibility. Trees of the Schley variety are about the most susceptible, and those of the Stuart have shown more resistance than others observed.

The water hickory, a species closely related to the pecan, is also susceptible. As known at present, the geographic range of the disease on pecan and water hickory seems to be limited mostly to the rich alluvial river-bottom land in restricted areas of Louisiana, Texas, Mississippi, and Arkansas.

Bunch disease appears to be infectious, but no parasite has been consistently found associated with diseased growth. In some respects symptoms resemble those of some virus diseases of other woody plants such as peach yellows.

Control

Little is definitely known about the control of bunch disease; hence control measures can only be suggested. It is a sound practice to avoid the use of bud or scion wood from diseased trees for propagation. Also, the use of diseased pecan and water-hickory trees as stocks should be avoided in working over native stands to standard varieties. As a precautionary measure to avoid the possible spread of the disease to valuable stands of pecan trees, diseased pecan and water-hickory trees growing wild in the vicinity of orchards should be destroyed, and care taken to prevent the survival of sprouts. The pruning out of diseased branches in lightly affected trees, the cut being made some distance back from any signs of the disease, may eradicate the disease from a tree. Once a lateral branch is affected back to the trunk or main part of a tree, there is little hope of preventing its gradual spread through the whole tree.

WINTER INJURY AND SUN SCALD

Because winter injury to pecans annually causes damage of more or less severity to many young trees, it is considered a rather serious problem by owners of young orchards. The symptoms are rather striking. Trees injured so severely that they will die may put out leaves in the spring as if normal and grow for several weeks on the food stored in the trunk and limbs, then suddenly wither and die. An examination of such trees when they wilt shows that parts of the trunk have been previously injured; the inner bark is dis-

colored and has a sour smell. The original injury may have been confined to a narrow band near the surface of the ground, but by girdling the trunk it caused the tree to die above the ground. The roots of affected trees seldom die, but sprout from below the dead parts (fig. 61). Shot-hole borers usually attack and riddle the trunk with many small holes soon after it has been injured. Growers consequently often attribute the dying of the trees to borer infestation. This type of injury is termed "winter injury."

FIGURE 61.—Winter injury of a young pecan tree. The leaves developed normally early in the spring and then died in May. Later in the season sprouts formed from the uninjured roots.

Often the injury is not so severe as described above because only one side of the tree trunk is affected. The injury will not be seen except on rather careful examination. At first it is characterized by a discolored strip of bark usually located a few inches above the ground level extending for varying distances up the tree trunk only on the south or southwest side. Later the bark on the injured area will appear sunken and dead and will crack where it meets the live tissue. The injured part of the trunk is usually invaded by shot-hole and flatheaded apple tree borers. The flatheaded apple tree borer may later completely girdle the tree and cause its death. This type of injury is often referred to as sun scald, since it is similar to a sun scald which occurs in the summer.

Winter injury is caused by sudden or excessive changes in temperature during the late fall and winter or early spring. Young trees 3 to 5 years old that have made a late growth are the most susceptible; trees over 9 or 10 years of age are seldom affected. To guard against winter injury, young orchards should not be given deep cultivation or nitrogenous fertilizers during the latter half of the growing season. If the growth of the trees is stimulated during the fall, their susceptibilty to winter injury is increased. Loss of young trees by winter injury can be entirely prevented by wrapping the trunk of each tree during the fall with a burlap sack, as shown in figure 62.

Cankers resulting from sun scald are very similar to those resulting from winter injury. Sun scald occurs chiefly on newly planted or recently established orchard trees, or on trees that have been severely cut back for top working. The cankers occur on parts of the tree exposed to the rays of the sun from the south or southwest. Injury

is followed by the invasion of borers, the flatheaded apple tree borer often completing the girdling started by sun scald. It is not definitely known why such injury occurs. Transplanting or severe cutting back probably predisposes the tissues to injury by temperatures which are critical.

Shading by natural or artificial means prevents the injury. Therefore, less injury from sun scald will result by heading trees low, by shading the tree trunk on the south side with a board 6 or 8 inches wide, by wrapping the tree trunk with burlap or similar material, or by leaving small branches arising below the head on young trees to grow to furnish shade until danger of injury is past.

FIGURE 62.—Method of wrapping young pecan trees with burlap or similar material to prevent winter injury.

IMPORTANCE OF GOOD ORCHARD CARE AND DISEASE CONTROL

Pecan leaves attain maximum size by the middle of May, and when free from injury by insects or diseases they retain their functioning powers until the first killing frost or freeze which usually occurs in November, an average growing season of about 200 days. Some years, when the first killing frost is unusually late, this period may be lengthened by from 15 to 30 days.

The vigor of the trees and more especially the severity of the attack of leaf-destroying fungi are the most important factors that determine whether the leaves will remain on the trees and retain their functioning powers during the summer and the greater part of the autumn, or whether they will become spotted and drop during August, September, and October. There is a very intimate association between some of the foliage diseases and lack of tree vigor caused by improper care of the orchard; hence, methods of correcting the condition by improved orchard management cannot be too greatly emphasized.

Young vigorous orchard trees, especially on fertile soil, or which have been furnished with a nutritious fertilizer and are free from competition by weeds, grasses, or an intercrop, will be freer from disease and carry their leaves in better condition throughout the summer. Likewise trees growing near farm buildings, on garden lots, or lawns, and along city streets, if not crowded by other trees, ordinarily carry their foliage until late autumn. The foliage on trees growing in low places in orchards where moisture, nitrogen, and mineral elements are more abundant, is better preserved at the

end of the growing season than that on trees growing nearby in drier and less fertile soil. Trees in bearing orchards that have been fertilized, cultivated frequently enough to keep down weed growth, and well cared for otherwise, especially if they have been properly sprayed, will carry their foliage in excellent condition until the first freeze.

On the other hand, trees in neglected, crowded, uncultivated orchards in which weeds, grasses, and brambles are allowed to take possession of the soil and compete with the trees for moisture, nitrogen, and other food-forming elements are the first to lose their leaves. The functioning power of leaves on such trees is greatly reduced after about the first of August owing to severe spotting by foliage-destroying fungi. Trees in the condition just described start growth slowly in the spring because of low food reserves resulting from poor foliage during the previous years and, further, because of the depletion of nitrogen or any other essential elements in the soil through weeds and grasses that start growth earlier in the spring than does the pecan. Trees growing in such unfavorable environments cannot be expected to show any improvement or increased production of nuts but instead will gradually decline in vigor from year to year.

All the common and most destructive pecan-foliage diseases except the downy spot and vein spot are easily controlled, and the grower can perform no operation in a pecan orchard that generally will yield more striking results in the preservation of the foliage throughout the summer and fall than spraying. Figure 63 shows a typical example of pecan-foliage preservation as the result of spraying and good cultural management of the orchard, as compared with figure 64, which illustrates an adjacent orchard not sprayed and given only indifferent cultural treatment.

SPRAYING MATERIALS, METHODS, AND EQUIPMENT

Spraying is the most effective means of controlling the greater number of insects and fungus diseases that attack pecan nuts directly or that cause foliage injury and reduce the yield indirectly. Since the ultimate aim of spraying is to obtain a greater yield of nuts than would be obtained without spraying, it is apparent that the expense of spraying will not be justified if the trees are low in productivity from neglect, crowding, or poor fertility of the soil. In order that spraying may be done intelligently and efficiently, the pecan grower should have a practical knowledge of the nature of the insects and fungus diseases he has to combat together with a knowledge of the methods of controlling them. Some insects cannot be effectively controlled by spraying, and mechanical means are resorted to.

Insects attacking the pecan may be divided into two classes—sucking insects and chewing insects. The obscure scale, phylloxera, and pecan aphids obtain their food by sucking the sap from the plant and are combated by the use of contact insecticides such as oil emulsions and nicotine. The pecan leaf casebearer, the fall webworm, and the walnut caterpillar, which actually eat the foliage or portions of the nuts, are destroyed by poisoning their food. Calcium arsenate

FIGURE 63.—Well-preserved pecan foliage as the result of spraying and good cultural treatment. Photograph taken November 2. Compare with figure 64.

FIGURE 64.—Typical condition of many pecan orchards during early autumn. Defoliation caused by foliage diseases. This orchard was not sprayed, fertilized, or cultivated. Photograph taken November 2. Compare with figure 63. The orchards shown in these two figures adjoin.

and lead arsenate are standard materials used in controlling this class of insects.

With the exception of scab, all the important fungus diseases of the pecan affect only the foliage. Among the leaf spots are vein spot and liver spot, present principally in portions of Texas, Louisiana, and Arkansas; and downy spot, blotch, and brown leaf spot, present and sometimes epidemic throughout the southern pecan belt, except in some portions of North Carolina and South Carolina. Any one of these diseases is capable of doing a great amount of damage to pecan foliage, but it is not unusual to find two, three, or even four of them in an orchard. One at least is usually sufficiently prevalent each year in most orchards to cause some spotting of the foliage, or in extreme cases partial to complete defoliation.

Most of the fungus diseases of the pecan are effectively controlled by spraying with bordeaux mixture. The following spray schedule is recommended for controlling scab: One application of 4–1–100 bordeaux mixture early in the spring before pollination, and after pollination three applications of 6–2–100 bordeaux mixture at 3- or 4-week intervals. Vein spot will require at least as much spraying as scab. Downy spot can be fairly well controlled with one prepollination application of 4–1–100 bordeaux mixture followed by one application of 6–2–100 bordeaux mixture between the middle of May and the middle of June. For such diseases as blotch, brown leaf spot, and liver spot, which have late infection periods, an application of 6–2–100 bordeaux mixture about the middle of May and a second application of the same spray about 30 days later should result in satisfactory control. Full-season spraying against scab or vein spot will at the same time control other foliage diseases. Precautions in using bordeaux mixture have been given in the discussion of spraying against scab.

SPRAY MATERIALS

BORDEAUX MIXTURE

Bordeaux mixture consists of copper sulfate, lime, and water in varying proportions. Several satisfactory methods have been developed for making it, but for simplicity of equipment, economy of labor, and uniformity of product it is recommended that either the powdered or the "snow" form of copper sulfate (bluestone) and hydrated lime be used. These forms of copper sulfate dissolve rapidly in cold water. Hydrated lime as ordinarily sold in the Southeastern States, especially that manufactured in Alabama and Tennessee, is usually satisfactory. It should be fresh, because when exposed to air for some time it carbonates and becomes ineffective. Hydrated lime has several advantages over stone lime; it is already properly slaked when purchased, it is relatively free from grit when properly manufactured, and a suspension or "milk" may be prepared in less time than is required with stone lime. The only equipment necessary is a bucket, tub, or keg in which the lime can be mixed with enough water to make a milk of lime that pours readily.

In the formula for bordeaux mixture the quantity of copper sulfate is given first, that of hydrated lime next, and that of water last. A 6–2–100 bordeaux mixture is prepared from 6 pounds of copper sulfate, 2 pounds of hydrated lime, and 100 gallons of water. If the

spray tank holds 300 gallons, three times these quantities will be required when that strength of bordeaux mixture is designated. A 6–2–100 bordeaux mixture for use in a 300-gallon spray outfit may be prepared in the following manner: Weigh out 18 pounds of copper sulfate and 6 pounds of hydrated lime. Mix the hydrated lime with water to make a milk of lime. Dissolve the copper sulfate by placing it in the strainer of the spray tank or in a burlap sack and allowing the inflowing water to pass through it while the tank is being filled. When the spray tank is about three-fourths full and all the copper sulfate is dissolved, add the milk of lime slowly with the agitator running. Complete the filling of the tank with water. If a spreader or insecticide is to be used, it should be put in after the milk of lime has been added. If a 4–1–100 bordeaux is to be prepared, only 12 pounds of copper sulfate and 3 pounds of hydrated lime are necessary for making 300 gallons.

Fortunately, the insecticides commonly used to combat insects of the pecan are compatible with bordeaux mixture; so it is possible to spray against insects and diseases in the same operation.

LEAD AND CALCIUM ARSENATES

Lead arsenate and calcium arsenate are generally sold in the form of a powder, formerly white, but now usually colored pink as a safety measure. Calcium arsenate contains more arsenic and is cheaper per pound than lead arsenate. Both arsenicals, however, especially the calcium compound, are liable to cause foliage injury when used alone in humid climates. As manufactured commercially they contain small quantities of arsenic that are soluble in water, and when sprayed on pecan trees the water-soluble portion is absorbed by the foliage and burning results. To overcome this difficulty some material must be added to the spray to absorb the free arsenic or change it to an insoluble form. Bordeaux mixture as used for the control of various diseases of the pecan is the best material for this purpose. As a preventive of arsenical injury it may be used as weak as 2–1–100. Hydrated lime with arsenicals is used on some fruit trees, but it will not protect pecan trees from injury.

In arid or semiarid portions of the pecan belt lead arsenate is regularly used alone or with hydrated lime without apparent injury, but in humid sections a preventive of arsenical injury, such as bordeaux mixture, should always be added.

LUBRICATING-OIL EMULSIONS

The pecan grower may find need to use lubricating-oil emulsions during the dormant and delayed-dormant periods to control the obscure scale. He may prepare this emulsion himself, but it is usually preferable to purchase the material already prepared.[4] These emulsions are usually white, of creamy consistency, and contain from 50 to 85 percent oil. Since they contain oils that have not been chemically treated for the removal of substances that may injure the foliage, they should be used only during the dormant period.

The grower should follow carefully the manufacturer's directions for mixing. The quantities of concentrated oil emulsion required to

[4] For detailed information on lubricating-oil emulsions see Farmers' Bulletin 1676, Lubricating-Oil Sprays for Use on Dormant Fruit Trees.

make 100 gallons of diluted spray for various purposes are shown in table 1.

TABLE 1.—*Dilution table for use of stock lubricating-oil emulsions of different oil content*

Oil content of stock material (percent)	Quantity of stock needed to obtain a given percentage of oil in 100 gallons of solution					Oil content of stock material (percent)	Quantity of stock needed to obtain a given percentage of oil in 100 gallons of solution				
	1 per cent	2 per cent	3 per cent	4 per cent	5 per cent		1 per cent	2 per cent	3 per cent	4 per cent	5 per cent
	Gallons	*Gallons*	*Gallons*	*Gallons*	*Gallons*		*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*
50	2	4	6	8	10	75	1½	2¾	4	5½	6¾
55	2	3¾	5½	7½	9¼	80	1¼	2½	3¾	5	6½
60	1¾	3½	5	6¾	8½	85	1¼	2½	3¾	4¾	5¾
65	1¾	3¼	4¾	6¼	7¾	90	1¼	2¼	3½	4½	5½
70	1½	3	4½	5¾	7¼						

SUMMER-OIL EMULSIONS

The lubricating-oil emulsions for dormant spraying, when applied at effective strengths, are unsafe to use on trees in foliage. Summer-oil emulsions are chemically inert and much less likely to injure foliage or nuts, especially when used at strengths specified for the control of the pecan nut casebearer or with nicotine sulfate in aphid control. The emulsions should contain not less than 80 percent of oil having a viscosity of not more than 70 seconds by the Saybolt test and an unsulfonated residue of at least 85 percent.

FISH OIL

Fish oil is sometimes used as a sticker for arsenicals, and it has also been used effectively in combination with nicotine sulfate for the control of the pecan nut casebearer. It should contain not more than 5 percent of free fatty acid. Fish oil is manufactured from several kinds of fish, but the oil most commonly used for orchard spraying in the eastern part of the United States is known in the trade as choice light pressed menhaden oil.

NICOTINE

Nicotine is an extract obtained from the stems and leaves of tobacco, mostly from the waste products in cigar and cigarette manufacture. It is usually sold as nicotine sulfate, containing 40 percent of actual nicotine. The nicotine sulfate form is not rapidly volatile and is employed chiefly in the preparation of orchard sprays. To control aphids, nicotine sulfate must be combined with some alkaline material to liberate the nicotine more rapidly. Bordeaux mixture is effective for this purpose, and soap is often used as a spreader.

CARBON DISULFIDE

Carbon disulfide is a heavy, volatile, and inflammable liquid which is occasionally injected into burrows in trees for the control of boring insects. When mixed in certain proportions with air, it is very explosive. Extreme care should therefore be used, both in storing and in using this material, to avoid undue heat and open flames or sparks of any kind.

THE SPRAY OUTFIT

Spray machines equipped with motors capable of developing from 15 to 20 horsepower and having a pump capacity of from 25 to 35 gallons per minute are recommended for pecan trees. A tank holding 300 gallons or more of spray mixture is most generally used. The pump should have a capacity greater than that required to operate at least two spray guns; one gun should be of the long-distance mist type capable of discharging from 15 to 20 gallons of liquid per minute, and the other of a smaller type that will discharge 5 to 6 gallons per minute. The motor must have sufficient power to operate the pump with both guns open and yet maintain a pressure of at least 300 to 400 pounds per square inch.

Each spray outfit should be provided with two leads of hose. The one that conveys the liquid to the long-range gun operated from the tower should be three-fourths of an inch in inside diameter and need not be more than 15 to 20 feet in length. The hose that carries the spray to the smaller spray gun used on the ground can be one-half inch in diameter, but should be 50 to 75 feet long, according to the distance between the trees.

A tower built on the tank of the sprayer is a necessary adjunct to any spray outfit used in pecan orchards containing trees more than 40 feet high.

Pecan growers as a rule have attempted to spray too many trees with limited equipment. As a result the applications have not been well timed, the spray operators have been compelled to sacrifice thoroughness for speed, and the machines have been worked to full capacity for days at a time with little attention to repairs and adjustments.

APPLYING THE SPRAY

In applying sprays to pecan trees the purpose of the particular application should be kept carefully in mind. For instance, the first cover spray in late spring or early summer is applied chiefly for the control of scab and downy spot and is made at a time when most of the leaves are susceptible to infection. Thorough spraying of the foliage is therefore essential, and effective work at that time should eliminate early infection to a large extent. On the other hand, the later sprays for the control of scab should be applied primarily to the nuts themselves, and since a large percentage of the early scab spots appear on the upper portion of the nuts, the spray directed from the top of a tower should furnish better protection than that directed from the ground. When spraying for control of the pecan nut casebearer it is necessary that all the nuts be completely covered, but for control of the leaf casebearer the spray should be applied to the under surface of the leaves where that species feeds at that time of the year. In spraying for aphids the foliage throughout the tree should be well covered.

The spray machine should be drawn along one side of the tree row and back along the opposite side. In spraying large pecan trees the machine should pause at least twice in passing each tree to permit the nozzle operators to cover all parts within range. The first stop should be made while approaching the tree, and the second just after passing the center of the tree. The exact position of the stop in rela-

tion to the tree will depend upon the direction and velocity of the wind and also upon the position of the larger branches on the side being sprayed. The operator should always take advantage of open spaces between large limbs to spray distant parts of the treetop. The man with the ground lead should concern himself chiefly with the lower branches and the inner lower part of the tree, while the man in the tower should spray the remainder of the tree.

If a large orchard is to be sprayed, much time and expense will be saved if the water and spray materials are conveyed to the spray outfit in a supply tank having a capacity equal to that of the spray tank. The spray machine can then be operated continuously except for the short time required to transfer the water from the supply tank to the spray tank and prepare the spray solution.

COMBINED SPRAYS FOR INSECT AND DISEASE CONTROL

When necessary it is possible to combine in one mixture the spray material recommended for the control of insects with that recommended for fungus diseases, and thus save the time and labor required to make separate applications. The spray schedule for combating pecan insects and diseases given in table 2, if carefully followed, will give satisfactory control of most of the important diseases and many of the insect pests. For many of the insects, however, a general spray schedule is not satisfactory, and the details of the control program must be worked out to fit local conditions.

TABLE 2.—*Spray program for control of pecan insects and diseases*

Name and time of spray	For control of—	Materials	Remarks
First cover or prepollination spray. When first leaves are half grown.	Scab, downy spot, vein spot.	4–1–100 bordeaux mixture.	A very important disease spray.
Second cover spray. About time tips of small nuts have turned brown.	Scab, pecan nut casebearer,[1] aphids, blotch, brown leaf spot, liver spot, vein spot, downy spot, rosette.	6–2–100 bordeaux mixture, nicotine sulfate 13 ounces, zinc sulfate 4 pounds.	Important spray to protect the nuts and foliage. Cover nuts and leaves thoroughly. Use zinc sulfate only if rosette is present. Important spray for pecan nut casebearer and should be applied at the proper time to obtain good results.
Third cover spray. 3 weeks after second cover spray.	Scab, aphids, blotch, brown leaf spot, vein spot, liver spot, rosette.	6–2–100 bordeaux mixture, nicotine sulfate 4 ounces, zinc sulfate 4 pounds.	As the black pecan aphid infests the foliage on all parts of pecan trees, thorough applications are necessary. Use zinc sulfate only if rosette is present. If the fall webworm or the walnut caterpillar is usually abundant and a serious pest, add 2 pounds of calcium arsenate.
Fourth cover spray. 3 weeks after third cover spray.	Scab, pecan leaf casebearer, aphids.	6–2–100 bordeaux mixture, calcium arsenate 2 pounds, nicotine sulfate 4 ounces, zinc sulfate 4 pounds.	On varieties that do not scab and where it is necessary to control the pecan leaf casebearer, use 2–1–100 bordeaux mixture and 2 pounds of calcium arsenate. Bordeaux mixture is used in this case merely as a corrective for arsenical injury.

[1] For complete information on the control of the pecan nut casebearer, see text p. 5.

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